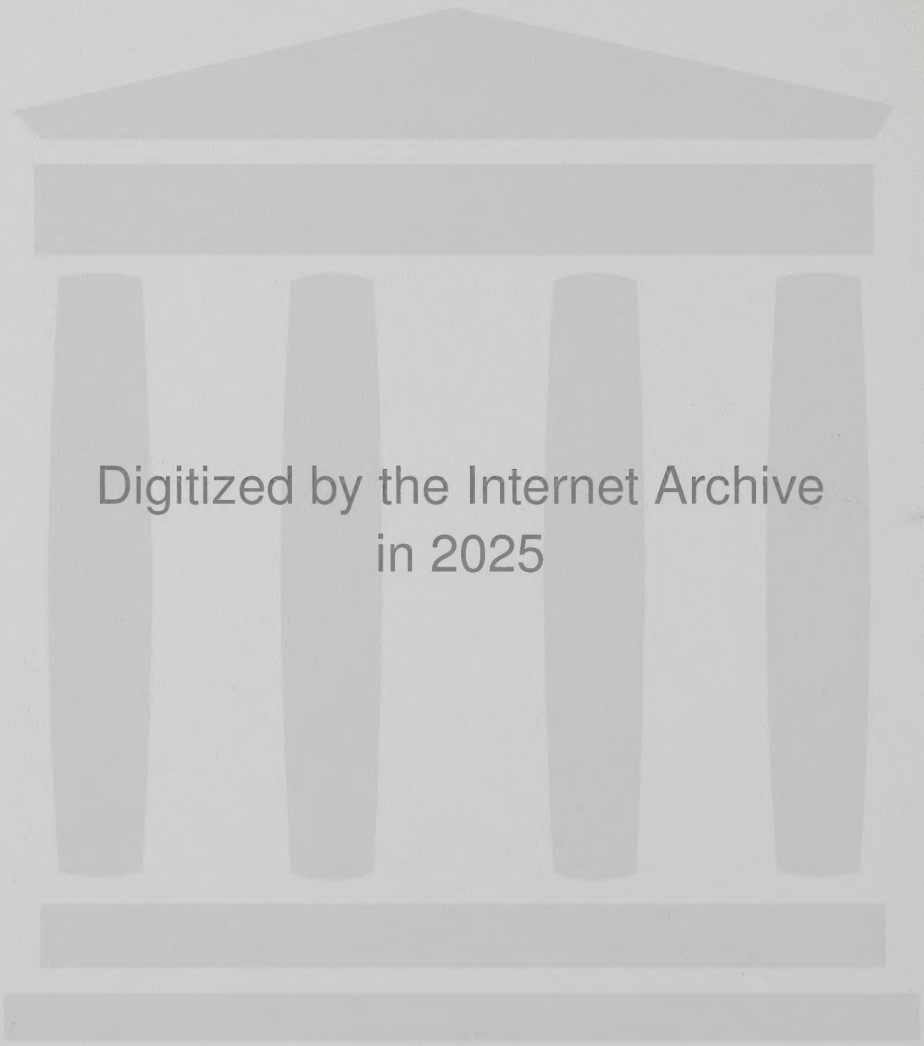
7411B

CALIBRATION AT A
KEYSTROKE SOFTWARE

used with **7404B 7449A A123**

Manual Set 2

FLUKE®


Digitized by the Internet Archive
in 2025

https://archive.org/details/manualsplus_11475

7411B

CALIBRATION SOFTWARE

used with ***7404B 7449A A123***

Manual Set 2

©1987, John Fluke Mfg. Co., Inc.
All rights reserved. Litho in U.S.A.

FLUKE®

7411B

CALIBRATION SOFTWARE

Operator Manual

P/N 797076
MARCH 1987
©1987, John Fluke Mfg. Co., Inc.
All rights reserved. Litho in U.S.A.

FLUKE®

1 Introduction 1-1

INTRODUCTION 1-1
ORGANIZATION 1-2
7411B DOCUMENTATION 1-3
7411B Configuration Manual 1-3
7411B Procedure Writing Manual 1-3
7411B Introductory Training Manual 1-4
MANUAL USAGE AND PERSONNEL 1-5
TRAINING 1-7

2 General Information 2-1

INTRODUCTION 2-1
Software Description 2-1
System Disks 2-4
CALIBRATION SOFTWARE DISKS 1 and 2 2-4
BLANK PROCEDURE DISK 2-4
EXAMPLE PROCEDURE DISK 2-5
CAL HISTORY MANAGEMENT DISK 2-5
CAL HISTORY DATA DISK 2-5
CALIBRATION RESULTS DISK 2-5
1722A CONTROLLER DISKS 2-6
BACKUP AND ARCHIVE DISKS 2-6
SYSTEM FEATURES 2-7
Touch Sensitive Overlay (TSO) Display 2-7
Menus 2-8
Display Keys 2-10
Alphanumeric Keyboard Screen 2-11
The Operator's Aid 2-12
Making Connections 2-14
Initializing The System 2-15
RESETTING THE DATE-TIME CLOCK 2-22

3 Operation Tutorial 3-1

INTRODUCTION 3-1
GETTING STARTED 3-4
ENTERING UUT SERIAL NUMBER AND CODE 3-6
PRELIMINARY OPERATION 3-6
DC VOLTAGE CALIBRATION 3-7
ADJUSTING THE SYSTEM STIMULUS 3-7
POST-TEST SUMMARY 3-8
TEST FAILURE AND CALIBRATION ADJUSTMENT 3-9
CONTINUING WITH DC VOLTAGE CALIBRATION 3-10
PROCEDURE TERMINATION AND RESULTS OPTIONS 3-11
UUT RESULTS LISTING 3-12
SAVING CALIBRATION RESULTS ON A DISK 3-13
RETURNING TO THE SYSTEM DIRECTORY 3-15

4 System Software Overview 4-1

INTRODUCTION 4-1
7411B SYSTEM SOFTWARE SYSTEM DIRECTORY 4-2
Calibrate an Instrument 4-2
List, Copy, or Delete 4-3
Enter New Operator Name 4-3
Edit a Procedure 4-4
Cal History (Optional) 4-4
Edit Bar Code File 4-5
FORMATTING A NEW PROCEDURE AND RESULTS DISK 4-5
How the 7411B Directory Structure Works 4-7
Using 7411A Procedures in the 7411B System . 4-7

5 How to Calibrate an Instrument or Device 5-1

INTRODUCTION 5-1
Calibration 5-1
PROCEDURE SELECTION 5-3
Loading the Procedure 5-3
LOADING USING A BAR CODE READER 5-5
LOADING BY MANUALLY ENTERING THE UUT PROPERTY CODE 5-6
LOADING BY DIRECT SELECTION 5-7
Executing the Procedure 5-8

Graphic Locator 5-8
Making Connections 5-8
CONNECTIONS 5-9
DISCONNECTIONS 5-10
Adjusting the Stimulus or Display 5-11
CALIBRATION TEST RESULTS 5-14
EXAMPLE: PERFORMING A CALIBRATION TEST 5-16
ADJUSTING THE UUT 5-18
EXAMPLE: TEST REQUIRING ADJUSTMENT OF THE UUT ... 5-19
LISTING THE PROCEDURE 5-22
ENTERING NUMBERS 5-24
LISTING AND SAVING RESULTS 5-25
INSTRUMENT CALIBRATION ERRORS 5-28
Error in System Executive 5-28
No Procedures on Disk 5-29
Invalid Procedure 5-29
Not Enough Room on Disk 5-30

6 How to List, Copy, and Delete Procedures and Results 6-1

INTRODUCTION 6-1
OVERVIEW OF LIST, COPY, AND DELETE CAPABILITIES 6-1
File Listing Capabilities 6-1
File Copying Capabilities 6-2
File Deleting Capabilities 6-3
HOW TO LIST, COPY, AND DELETE FILES 6-3
How to List Files 6-4
LISTING PROCEDURES 6-6
LISTING RESULTS 6-7
LISTING THE BAR CODE FILE 6-9
LISTING THE CATALOG 6-9
How to Copy Files 6-10
COPYING PROCEDURES 6-11
COPYING RESULTS 6-13
COPYING THE BAR CODE FILE 6-14
How to Delete Files 6-15
DELETING PROCEDURES 6-16
DELETING RESULTS 6-17
ERRORS 6-19

7 Cal History Management 7-1

INTRODUCTION 7-1
PROTECTION OF CALIBRATION HISTORY INFORMATION ... 7-2
CAL HISTORY MANAGEMENT TUTORIAL 7-3
GETTING STARTED 7-4
Initializing the Data Disk 7-4
DEFINING THE REPORT 7-6
Selecting the Desired Data 7-6
Selecting the Desired Instruments 7-7
Listing of Information and Instruments 7-9
Saving the Report Definition 7-9
PRINTING THE REPORT 7-10
UPDATING THE DATA DISK 7-11
Appending Results to Cal History Data Files . 7-11
Modifying or Inserting Instruments 7-12
USING CAL HISTORY MANAGEMENT 7-13
CAL HISTORY MANAGEMENT DIRECTORY 7-14
UPDATE HISTORY DISK OPTION 7-14
Append Results to Files 7-15
UPDATE SELECTED INSTRUMENTS 7-16
UPDATE ALL INSTRUMENTS ON DISK 7-18
THE UPDATE PROCESS 7-18
CREATE NEW INSTRUMENT ENTRY 7-18
INSERT ANOTHER HISTORY DISK 7-18
SKIP INSTRUMENT AND CONTINUE 7-19
Modify/Insert Instrument 7-19
SELECTION BY SERIAL NUMBER OR UUT CODE 7-20
SELECTION FROM DISPLAY 7-21
MODIFYING AN EXISTING INSTRUMENT ENTRY 7-22
Modify Instrument Data 7-22
Modify History Data 7-24
Neither Modify Instrument
Data Nor Modify History Data 7-25
Delete Instrument 7-25
Initialize History disk 7-26
PRINT REPORT 7-26
Print Report on Printer 7-27
Print Report on Screen 7-27
Select Report to Print 7-27

DEFINE REPORT 7-28
Delete a Report Definition 7-28
Modify/Create a Report 7-29
CREATING A NEW REPORT 7-29
SAVING THE NEW REPORT DEFINITION 7-36
MODIFYING AN EXISTING REPORT 7-37
SAVING THE MODIFIED REPORT DEFINITION 7-38
FIELD NAMES, SIZE, AND FUNCTION 7-39
SYSTEM PASSWORD 7-39
Defining the Password 7-40
Using the Password 7-40

FIGURE	TITLE	PAGE
2-1.	Touch Sensitive Display	2-8
2-2.	Sample Menu	2-8
2-3.	Display Keys	2-10
2-4.	Alphanumeric Keyboard Screen	2-11
2-5.	Operator's Aid	2-13
2-6.	Connection Display	2-15
2-7.	Disk Loading Slot	2-16
2-8.	Disk Insertion	2-16
2-9.	Hello Display	2-17
2-10.	Self Test Display	2-18
2-11.	Loading Display	2-18
2-12A.	Command File Active Display	2-19
2-12B.	Command File Active Display with Date Request	2-19
2-12C.	Date Entry	2-20
2-13A.	Loading Calibration Software Display	2-20
2-13B.	Final Software Loading Display	2-21
2-14.	Fluke Calibration System Directory	2-22
2-15.	Prompting Messages for Date and Time	2-23
3-1.	7411B Example Tutorial Procedure	3-2
3-2.	Tutorial Procedure Results	3-3
3-3.	Results Menu	3-11
3-4.	Listing Device Menu	3-12
4-1.	Instrument Calibration Directory	4-2
4-2.	Missing Instrument Display	4-3
5-1.	Procedure Selection Display	5-3
5-2.	Alphanumeric Keyboard Screen to Enter Property Code	5-6
5-3.	Standard Connection Message	5-9
5-4.	Courtesy Connection Message	5-9
5-5.	Disconnection Message	5-10
5-6.	Adjust Stimulus Display	5-12
5-7.	Test Results Display	5-13

5-8. Range/Function Message 5-16
5-9. Test Results (Passed) Display 5-17
5-10. Sample Adjustment Message 5-18
5-11. Test Results (Failed) Display 5-19
5-12. First Adjustment Message 5-20
5-13. Second Adjustment Message 5-21
5-14. List Procedure Display 5-22
5-15. Enter Numeric Value Display 5-24
5-16. List/Save Results/Summaries Menu . 5-25
5-17. List Device Menu 5-26
5-18. Error in System Executive Display..... 5-28
5-19. Error During Calibration Display . 5-29
6-1. Main List, Copy, and Delete Menu . 6-3
6-2. List Menu 6-4
6-3. List Source Menu 6-4
6-4. List Device Menu 6-5
6-5. List Procedure Selection Menu 6-6
6-5a. Procedure Listed on Screen 6-7
6-6. List Results Selection Menu 6-8
6-6a. Results Listed on Screen 6-8
6-6b. Catalog Procedure Display 6-9
6-6c. Catalog Results Display 6-10
6-7. Main Copy Menu 6-10
6-8. Copy Source Menu 6-11
6-9. Copy Procedure Selection Menu 6-12
6-10. Result Selection Menu to Copy 6-13
6-11. Destination Device Menu 6-14
6-12. Delete Menu 6-15
6-13. Delete Source Menu 6-15
6-14. Delete Procedure Menu 6-16
6-15. Delete Results Selection Menu 6-18
6-16. List, Copy and Delete Error Display 6-19
7-1. Cal History Management Directory ... 7-14
7-2. Enter Update Selection Menu 7-15
7-3. Update Choice Menu 7-17
7-4. Instrument Selection Display for Update ... 7-17

7-5. Selection Technique Menu 7-19
7-6. Instrument Selection Display
for Update From Display ... 7-21
7-7. Modify Instrument Data Display ... 7-22
7-8. Print on Printer/Screen Menu 7-26
7-9. Select Report Definition Task Menu 7-28
7-10. Select Report to Modify Display .. 7-29
7-11 Input Report Name Display 7-30
7-12. Instrument Information
Selection Display .. 7-30
7-13. Instrument Selection Field Display 7-35
7-14. Report Information Display 7-35
7-15. Report Selection Display 7-36

TABLE	TITLE	PAGE
5-1.	Adjust Stimulus/Match UUT Display Keys	5-11
5-2.	Test Results Display Column Headings	5-14
5-3.	Test Results Display Optional Keys	5-15
5-4.	Format Representation of Numbers	5-24
5-5.	Instrument Calibration Error Descriptions .	5-31
6-1.	List, Copy, and Delete Error Messages	6-20
7-1.	Entries for Modify Instrument Data	7-23
7-2.	Entries for Modify History Data	7-25
7-3.	Entries for Report Instrument Information .	7-31
7-4.	Entries for Report Instrument Selection ...	7-33
7-5.	Limits for Restricted Fields	7-39

Section 1
Introduction

INTRODUCTION

The 7411B Operator Manual describes how to operate a computer-aided calibration workstation (7405A, 7410A, or A123) or benchtop cluster (7404A, 7404B, 7409A, or user-configured using the 1722A). The manual includes examples and a step-by-step tutorial describing how to use the 7404B System to calibrate an instrument and handle data. This manual is intended for individuals who will operate the system.

NOTE:

A summary of the differences between the 7411A and 7411B Calibration Software is in Section 1 of the 7411B Configuration Manual.

ORGANIZATION

Section 1 How to Use This Manual
Describes the organization and contents of the 7411B Operator Manual.

Section 2 General Information
Describes the basic functions and features of the 7411B.

Section 3 Operation Tutorial
Contains a step-by-step approach to operating the 7411B, and provides the operator with a thorough introduction to the automated calibration process.

Section 4 System Software Overview
Describes the 7411B Software in detail and describes the other software packages that are used in the 7411B.

Section 5 How to Calibrate an Instrument or Device
Describes the calibration process in detail for the system operator.

Section 6 How to List, Copy, and Delete Procedures and Results
Describes how to use the List, Copy, and Delete Procedures and Results options of the 7411B.

7411B DOCUMENTATION

The 7411B Calibration Software is primarily supported by four major manuals in two volumes (binders). Volume 1 contains the Introductory Training Manual and the Procedure Writing Manual. Volume 2 contains the Operator Manual and Configuration Manual. In addition, Volume 2 contains two supplementary manuals: the 5200A-800 Manual and System Builder's Guide, both of which are used for reference purposes. Volume 1 also contains a supplementary manual, How To Use These Manuals.

This is the Operator's Manual. The following paragraphs briefly describe the other major manuals in the 7411B Manual Set. Refer to Volume 1, How to Use These Manuals, for more information.

7411B Configuration Manual

The Configuration Manual provides an overview of the software structure, the hardware relationships, and communication. Both hardware and software configurations are explained.

7411B Procedure Writing Manual

The 7411B Procedure Writing Manual explains how to write or modify calibration procedures. The manual is intended for technicians or engineers who have a working knowledge of instrument calibration. However, writing and modifying procedures does not require programming experience.

The last section in the 7411B Procedure Manual explains how to add or delete property numbers from the bar code file. Bar Code capability provides the means to automatically start up calibration procedures by reading a property code with a bar code reader.

7411B Introductory Training Manual

If you have little or no background in procedure writing, the 7411B Introductory Training Manual is a good place to improve your skills. In the 7411B Introductory Training Manual you will find FSC descriptions, exercises dealing with FSCs, and answers to the exercises. Use the 7411B Introductory Training Manual in conjunction with the 7411B Procedure Writing Manual to develop or enhance your procedure-writing skills.

MANUAL USAGE AND PERSONNEL

The 7411B System requires personnel to perform five separate tasks. All of these tasks may be performed by one individual (in a small organization) or many individuals may be required for a large organization. The following list describes the five separate tasks:

TASK	DUTIES
System Management	Format data management reports, direct software modification, establish calibration methods and timetables, and optimize procedures for automatic calibration.
Source Code Modification	Customize source code, add drivers format test reports. (Requires 7411B Source Code Manual)
Procedure Writing	Create or modify calibration procedures, using instrument manuals and metrology experience. Software programming experience is not required.*
System Operation	Use the 7411B to calibrate instruments, following the directions given by the System. No calibration experience is required for this task, although a familiarity with electronic equipment is an asset.
Maintenance	Service, troubleshoot, repair, and calibrate the component instruments of the System.

*Some experience in BASIC programming is needed to use the RUN and RUNE Function Selection Codes in a procedure.

Each of the tasks explained above requires the appropriate documentation for the person(s) performing that task. The following table lists the types of documentation required by the person(s) performing these tasks:

TASK	MANUAL	REMARKS
System Operation	Operator	This manual provides all the necessary information for the Operator of a 7411B-based, computer-aided calibration System.
Procedure Writing	Procedure Writing, Operator	The procedure writer should read through the Operator Manual to become familiar with the operator's tasks.
Maintenance Engineering	Instrument Manuals	The Service Engineer should briefly read through the individual Instruction Manuals of the System's component instruments to become familiar with their servicing requirements.

TRAINING

With only a little operation training, you can perform accurate and usable calibrations with the 7411B-based system. The 7411B is shipped with calibration procedures for many popular meters. These procedures allow you to use the System immediately to calibrate those instruments. An interactive menu-driven display guides the operator through the process, clearly defining each task. Most users find that a few minutes of familiarization is all that is necessary to allow them to use the System.

However, procedure writing training can be a great asset to those wishing to quickly learn the procedure writing process. The short Introductory Training Manual at the back of this binder will help you write your first procedures.

Fluke also offers a training course that explains more about system hardware and software and procedure writing. Contact your local Fluke representative for information on the 7400 Series System Training Course.

INTRODUCTION

This section describes the 7411B Calibration software. The 7411B, used in the Fluke 1722A Instrument Controller, provides automated control for a number of hardware units which can be combined to provide an automatic calibration system.

Software Description

The following disks are delivered with your 7411B system:

- Configuration Utility Disk

  This disk contains the configuration program to create the system software.

- Instrument Library Disk

  The Instrument Library disk contains a library of instrument drivers to be linked in during configuration to create the system software.

- Calibration Software Disk 1

  Unless the system has been pre-configured by Fluke, this disk is blank and created by following the instructions during configuration for a floppy disk system.

- Calibration Software Disk 2

  Unless the system has been pre-configured by Fluke, this disk is blank and created by following the instructions during configuration for a floppy disk system.

- Cal History Management Disk

  The operator will be prompted to load the Cal History Disk after loading Calibration Software Disks 1 and 2.

- Cal History Data Disk

  The Cal History Data Disk is only used while running the Cal History Management program.

- Calibration Results Disk

  The Calibration Results Disk may be used to store the results of a calibration. At the time of delivery it is blank, unless the system has been configured and tested at the factory; in that case, it will contain the results of the Functional Integration Test (FIT).

- Procedure Disk

  The Calibration Procedure Disk may be used to store calibration procedures. At the time of delivery this disk is blank. In addition to the blank procedure disk a number of disks is included containing example procedures.

- Bar Code Disk

  This disk is intended to store the property codes to be used by the Bar Code utility. In a hard disk based system, the property codes are stored on hard disk. The Bar Code file should be backed-up on the Bar Code Disk.

- Translator & Utilities Disk

  This disk contains a number of special routines:
  a. A routine to re-format the Winchester Disk
  b. A routine to create 7411B procedure floppy disks from 7411A procedure disks
  c. Routines to create 7411A calibration procedures from pre-7411A calibration procedures
  d. A routine to create 7411B results floppy disks from 7411A results disks

The 7411B Calibration Software performs two basic functions: procedure generation and editing, and execution of the calibration procedure. (The procedure itself is stored on a procedure or data disk in floppy disk systems, or must be copied from floppy disk onto the Winchester disk for a hard disk system.) Data disks contain raw information (such as the calibration procedure) that is used by the System Software during the execution of its tasks.

In addition to the two basic functions, the Calibration Software enables the operator to list procedures or test results on a printer, copy procedures and test results from one disk to another, transfer procedures and test results to or from a host computer, and delete procedures and test results from a disk. The software also allows the operator to store his or her name with the results generated during instrument calibration. Section 5 describes the procedures to perform these tasks.

System Disks

System Disks, Calibration Software Disks 1 and 2 are created during configuration using Configuration Utility and Instrument Library Disks. If you purchased the 7411B software separately from the hardware, you have to configure your system yourself. If you purchased the whole system as a unit from Fluke, you will receive the system software already configured.

In the case of a floppy disk based system, Calibration Software disks 1 and 2 are used to start up the Calibration system on power-up. For a Hard Disk system, the calibration system software will be loaded from the Winchester disk; the Calibration Software disks are not used in this case.

The following paragraphs describe the contents of these floppy disks.

CALIBRATION SOFTWARE DISKS 1 and 2

The Calibration Software Disks 1 and 2 contain the system object code necessary to write or modify a calibration procedure and calibrate UUTs. (You do not have to load this disk if your system has been configured as a hard disk system.) The disk interprets procedures and performs system actions and operator prompts. Section 4 provides a detailed analysis of its functions. Refer to the Procedure Writing Manual for information on writing calibration procedures.

BLANK PROCEDURE DISK

If your system has a Winchester disk, generally your procedures will be stored on hard disk. You can copy the procedures one by one, or all at the same time from floppy disk to hard disk. Backup floppies protect you from possible Winchester disk failures.

A Procedure disk is also supplied with the 7411B. This disk is used to store the calibration procedures that have been created using the 7411B Software. Each procedure is a series of tests, messages, and adjustments that calibrate a measurement instrument. The Procedure disk requires the object code contained on the Calibration Software disk for operation.

EXAMPLE PROCEDURE DISK

With your 7411B system, you will receive a number of example procedures on floppy disk.

CAL HISTORY MANAGEMENT DISK

The Cal History Management Disk provides the capability to archive test information about UUTs and to generate reports. Section 7 of this manual contains a description of this software.

CAL HISTORY DATA DISK

The Cal History Data Disk contains specific UUT information and calibration test history. The Cal History Management Software uses this data to perform general data management functions.

CALIBRATION RESULTS DISK

The Calibration Results Disk contains example results for use in system training. The results can be deleted if the operator wishes to use the Calibration Results Disk for actual system results. Section 4 of this manual describes how to create additional disks for procedures and results.

1722A CONTROLLER DISKS

There are three disks supplied with the 1722A. These disks are part of the 1722A Instrument Controller and are not used by the 7411B except when changing the command file for the 7411B. A blank disk is provided for storing BASIC programs and data. A Systems Diagnostics Disk provides troubleshooting for the 1722A. A 1722A System Disk includes the operating system for the Controller. These disks are not used during the operation of the 7411B. The 7411B Software Disk also includes BASIC for creating BASIC RUN programs.

NOTE:

For a hard disk-based system, BASIC programs must be stored on the WD0 partition of the Winchester disk.

BACKUP AND ARCHIVE DISKS

It is very important to store copies of certain 7411B software and data disks. These copies are often called archive or backup disks. It is suggested that a complete copy of all 7411B disks be stored in a safe and secure location. Regular archiving is imperative for disks such as the Cal History Data Disk where a destroyed disk would involve a catastrophic loss of information.

If your system is equipped with a Winchester disk, you are strongly advised to back up all the files on floppy disks as well. Software you should back up includes:

- The system software
- All procedures

- The Bar Code File, containing all property numbers and related information
- Results files

Practically, most of the changes occur in the result files. You are strongly advised to process or store all results at least on a daily or weekly basis.

Disks may be duplicated using the whole copy function of the 1722A FUP (File Utility Program) on the Controller. Refer to the 1722A System Guide for information on the FUP feature.

SYSTEM FEATURES

The following paragraphs describe the important features of the 7411B used in a system. These features rely on the (previously discussed) relationship between hardware and software.

Touch Sensitive Overlay (TSO) Display

The 7411B guides the operator through the calibration procedures by displaying messages and menus on the Controller's display, which includes a Touch Sensitive Overlay (TSO) (shown in Figure 2-1). The TSO allows the operator to enter responses and select items on the menu by touching the screen.

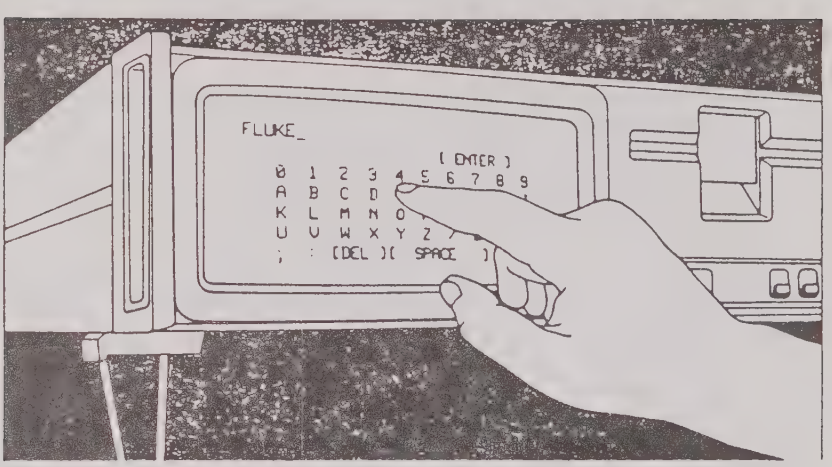


Figure 2-1. Touch Sensitive Display

Menus

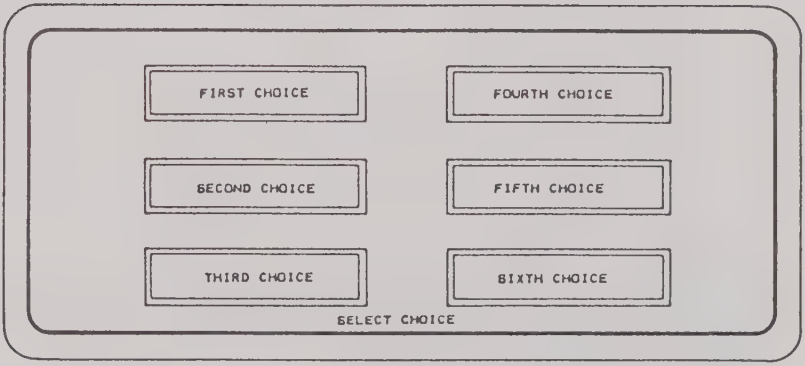


Figure 2-2. Sample Menu

Two types of menus are found in the 7411B system. The most common type is shown in Figure 2-2. It is generally used when executing a calibration procedure, listing, copying or deleting files, editing calibration procedures and the bar code file. The type shown in Figure 2-3 is used during system configuration and in Calibration History Management menus.

Figure 2-2 shows six possible locations for selections. In some menus the selection is immediately implemented, in others a confirmation is necessary; in that case the sixth location is used for "Execute Selection". As long as Execute Selection is not pressed, the prior selection can be recalled by pressing another display key. This form of menu was chosen to improve the ease of operation for most functions.

The Figure 2-3 style menu was used in the predecessor of the 7411B, the 7411A, which did not support the Winchester disk and the Bar Code reader.

You select an item on the menu by touching the display between the brackets next to the desired item. You must touch the display reasonably close to the center of the area between the brackets. If your eyes are too far above, below, or to the side of the Controller, causing you to view it from a sharp angle, you may miss the center of the displayed bracket. If this occurs, adjust the Controller so that you are looking directly at the display.

In general it is always possible to discard changes before they are actually included on floppy or hard disk; if they could override valuable current files, unless of course at confirmation time, you indicate that you really do want to store this new information.

Display Keys

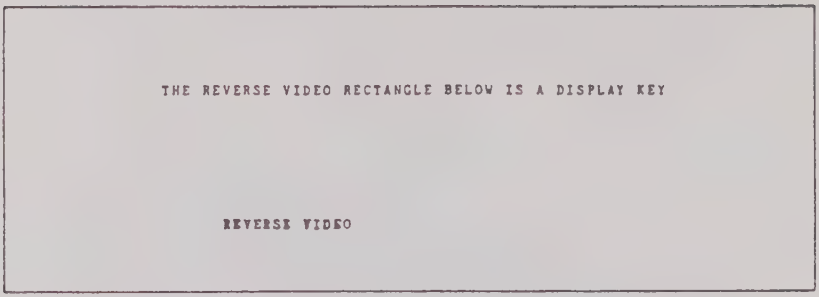


Figure 2-3. Display Keys

Display keys, or "soft keys" (illustrated in Figure 2-4), provide another method of entering responses to the 7411B. The display keys are displayed on the screen in reverse video, which means that the background is lighted instead of the letters. Responses are entered by touching the appropriate display key on the TSO. You can also enter a response by touching the corresponding display key on the Operator's Aid. This feature is discussed under the heading, "Using the Operator's Aid". The messages accompanying the display keys are generally self-explanatory and are supplemented, when necessary, in this manual.

NOTE:

The Operator's Aid is not supplied with the 7411B; it is supplied with the 7404A, 7404B, 7405A, 7409A, 7410A, 7449A, A123, and 7422A.

To select a display key, the operator must touch the display key reasonably close to the center of the highlighted area, similar to selecting an item from a menu display.

Throughout this manual, display keys are indicated by square brackets ([and]) around the displayed letters (e.g., the TERM display key is indicated as [TERM]).

Alphanumeric Keyboard Screen

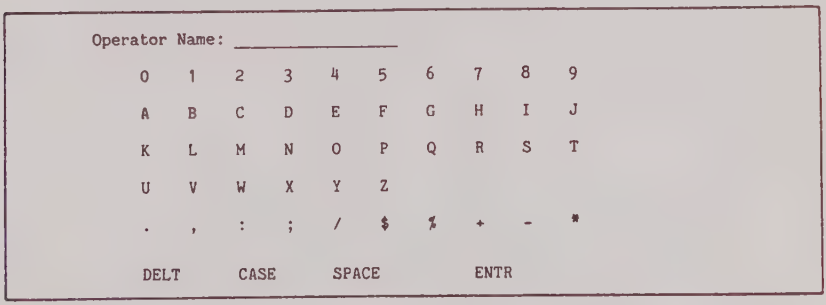


Figure 2-4. Alphanumeric Keyboard Screen

The System uses a special Alphanumeric Keyboard Screen shown in Figure 2-4 to allow the operator to enter letters, numbers, and symbols. This screen (used to enter the UUT code, UUT serial number, operator's name, and remarks) will be referred to in later sections. In most cases, up to 16 characters including blanks may be entered using this screen. The length of the underline indicates maximum entry length. Alphanumeric keyboard screen characters and symbols are indicated in text the same as display keys (see above).

The characters are displayed on the line on the top of the screen as they are entered. If a 1722A keyboard is installed, characters may also be entered from there. (If you are using the keyboard press the RETURN key instead of the Enter soft key.)

If your 7411B system is configured as a hard disk system, you will not have to enter UUT or property code, and UUT serial number, when using the bar code option of the 7411B. This information is read in automatically from the bar code file.

Characters may be deleted by touching [DELT]. One character is deleted each time [DELT] is touched, beginning with the last character entered.

Touching [CASE] changes the case of the letters. If the letters are in upper-case, touching [CASE] will change the case to lower-case; conversely, if the letters are in lower-case, touching [CASE] will change the case to upper-case.

Spaces may be entered by touching the blank ([ ]) rectangle between [CASE] and [ENTR].

Touch [ENTR] after making the entry.

The Operator's Aid

NOTE

The Operator's Aid is not supplied with the 7411B; it is supplied with the 7404A, 7404B, 7405A, 7409A, 7410A, 7449A, A123, and 7422A.

The Operator's Aid, shown in Figure 2-5, provides an alternate way to communicate with the System. LEDs are turned off and on to indicate whether a test has passed or failed, and buttons on the Operator's Aid allow the operator to enter responses to messages on the 1722A Display.

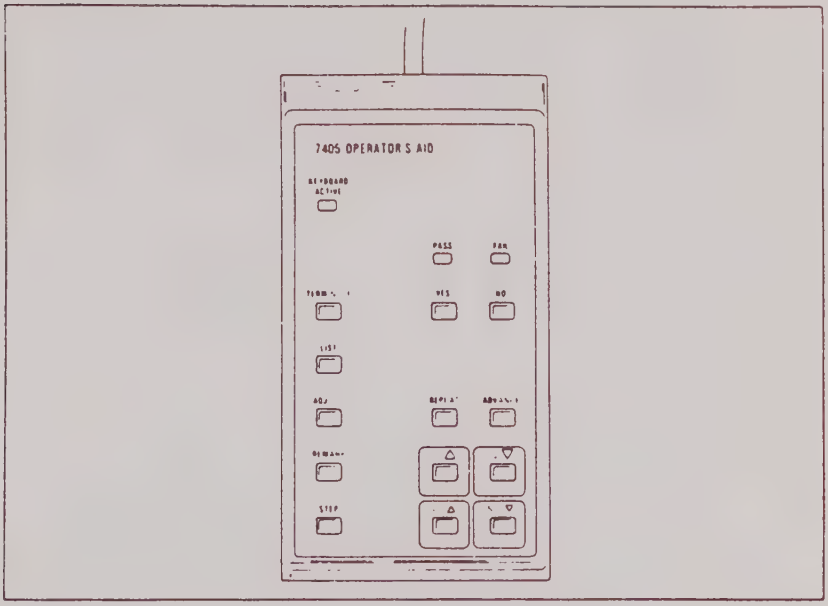


Figure 2-5. Operator's Aid

The keyboard active light indicates when the Operator's Aid can be used. The Operator's Aid can be used when this light is on.

The pass and fail lights show whether the UUT passed or failed the last test.

The buttons correspond to display keys on the Controller display. When the keyboard active light is on, responses may be entered either by touching the Controller display or pressing the corresponding button on the Operator's Aid.

The Operator's Aid plugs into the keyboard connector of the 1722A Controller. Note that you may plug it in even after a calibration has begun. However, it may not become immediately active. When the operator enters the response via the touch panel, the Operator's Aid becomes active for the next entry.

Making Connections

Connections and disconnections between instruments of the System and the UUT are required during the execution of the calibration procedure.

WARNING

POTENTIALLY DANGEROUS VOLTAGES MAY BE PRESENT ON THE TERMINALS OF THE SYSTEM. TO AVOID ELECTRICAL SHOCK HAZARD, CAREFULLY FOLLOW THE CONNECT AND DISCONNECT MESSAGES THAT APPEAR ON THE CONTROLLER. DO NOT MAKE CONNECTIONS AT ANY OTHER TIME OTHER THAN DIRECTED BY THE SYSTEM.

The 7411B prompts the Operator with a displayed message any time a connection (or disconnection) is to be made. An example of a connection message is shown in Figure 2-6. When a connection message appears, carefully follow the directions displayed, and then press the [ADV] display key or the ADVANCE key on the Operator's Aid.

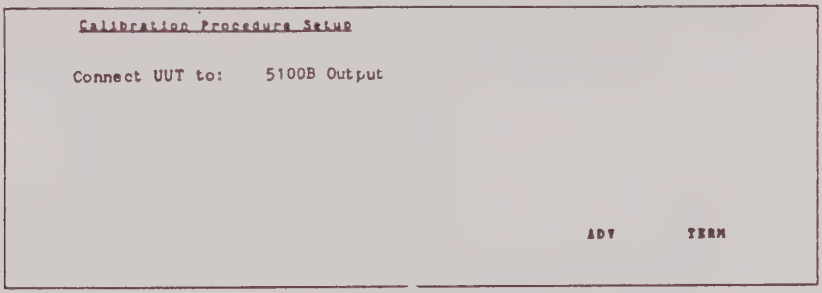


Figure 2-6. Connection Display

Initializing The System

Once your system has been installed, you are ready to begin calibrating instruments. The first step in the automated calibration process is to initialize the system.

Initialization is extremely simple when your system has been configured as a hard disk system: you just turn on the power to the system and typically all files needed are immediately available after the Winchester disk drive has come up to speed. If your 7411B system has been configured as a floppy disk based system, initialization consists of loading the 7411B Software into the Controller, selecting and loading the calibration's procedure disk.

In both floppy-disk and hard disk based systems, you may have to reset the internal date-time clock of the Controller.

Use the following procedure to initialize a floppy-disk based system:

1. Energize the Controller.

2. Open the disk drive latch by pressing at the top of the square latch as shown in Figure 2-7.

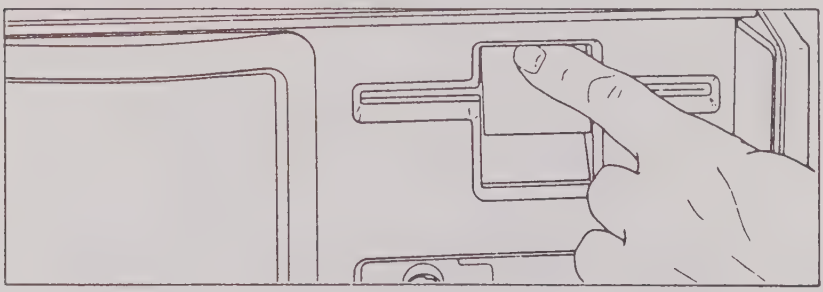


Figure 2-7. Disk Loading Slot

3. Insert the 7411B Software disk, label side up, into the disk drive as shown in Figure 2-8.

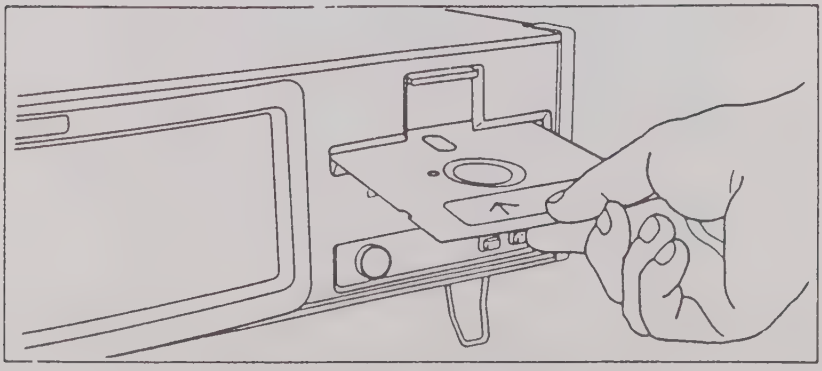


Figure 2-8. Disk Insertion

4. Seat the disk in the disk drive by slowly closing the drive's latch part way. Perform this step several times to ensure that the disk is seated. When the disk is fully seated, latch the drive closed by pressing in on the bottom of the latch.

5. Press the RESTART button on the front panel of the Controller.

6. During the next few minutes, the Controller displays the messages shown in Figures 2-10, 2-11, and 2-12.

7. The Controller next displays either the message shown in Figure 2-12A or 2-12B. If the display shown in Figure 2-12A appears (which is the usual display), it is replaced after a brief pause by the display shown in Figure 2-13A. If the display shown in Figure 2-12B appears (indicating that the internal date-time clock of the Controller needs to be reset), perform the following steps to reset the date-time clock of the Controller.

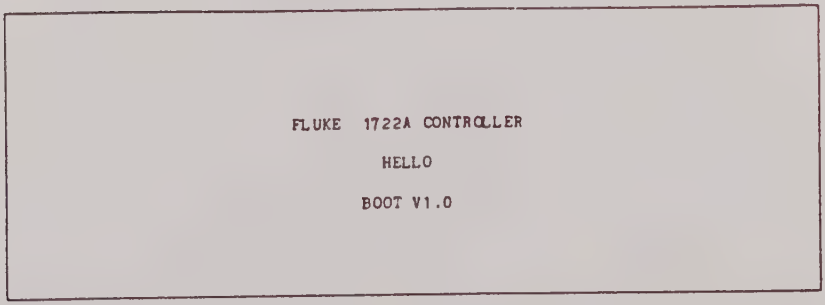


Figure 2-9. Hello Display

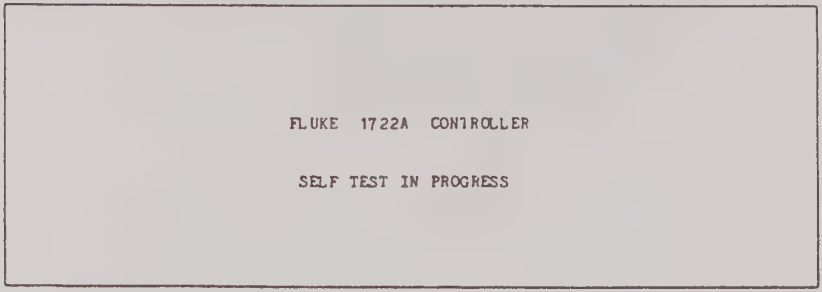


Figure 2-10. Self Test Display

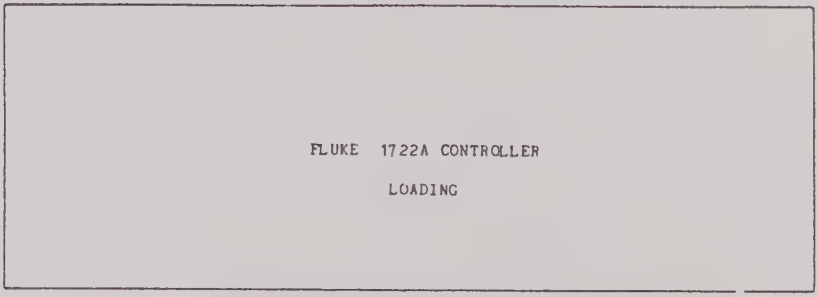


Figure 2-11. Loading Display

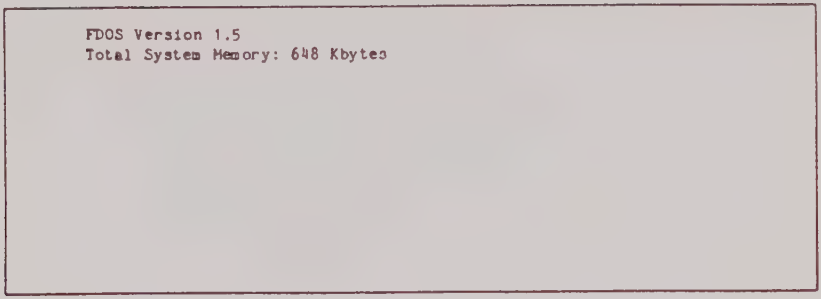


Figure 2-12A. Command File Active Display

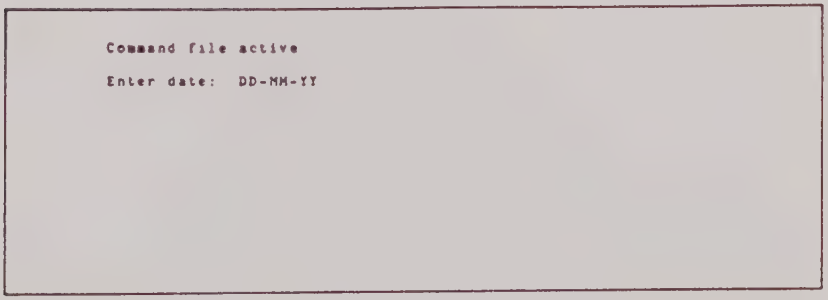


Figure 2-12B. Command File Active with Date Request

a. Connect the Controller's keyboard to the Controller.

b. Enter the correct date and time as shown in Figure 2-12C. Entries may be separated with

any non-numeric character. The time is entered as a 24-hour clock (i.e., 8:20 p.m. is entered as 20:20)

c. Press <RETURN>. The Controller then continues to load the calibration procedure from the Procedure disk.

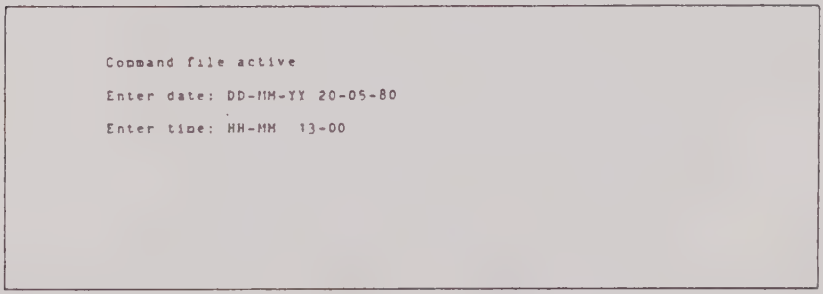


Figure 2-12C. Date Entry

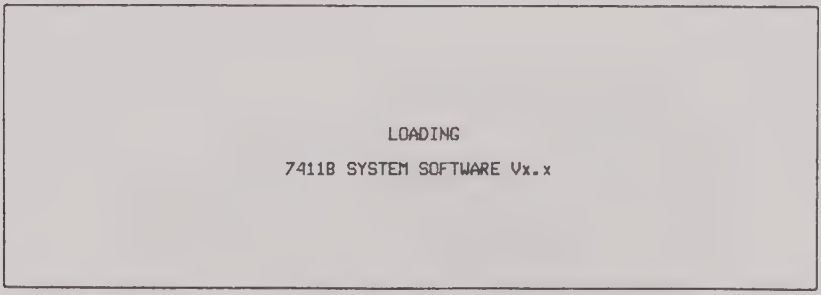


Figure 2-13A. Loading Calibration Software Display
(Vx.x corresponds to your version)

8. The message similar to the display shown in Figure 2-13A is displayed for approximately 2 minutes. The System then displays the message shown in Figure 2-13B. Remove the Procedure disk and press the [ADV] display key.

9. The Controller displays the System Directory as shown in Figure 2-14. This indicates that the System is now ready to begin calibrating the selected instrument.

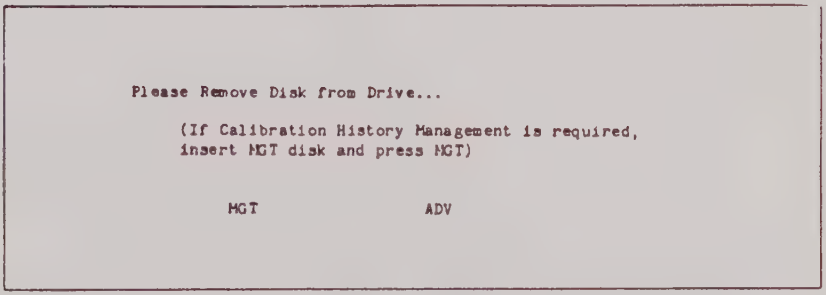


Figure 2-13B. Final Software Loading Display

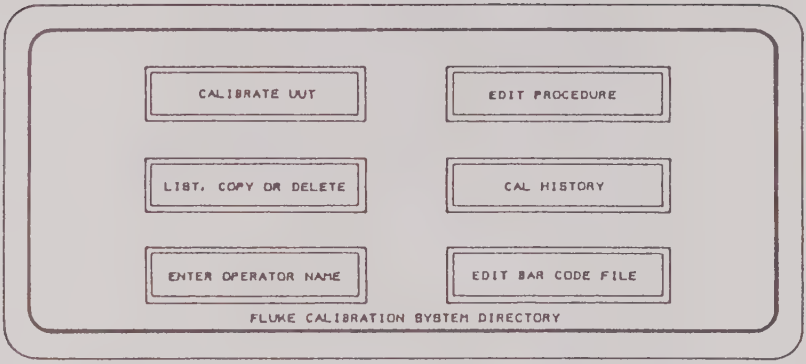


Figure 2-14. Fluke Calibration System Directory

RESETTING THE DATE-TIME CLOCK

Once the date and time are set, either at the factory or when the system is installed, the Controller maintains the date and time indefinitely unless the power is off for 90 days or more or if the printed circuit boards are removed from the Controller. However, there may be circumstances where the operator will need to change the date and time.

To change the date and time in a floppy-disk based system, follow the all steps listed below. If you have a hard disk based system, skip step 1.

1. Load the 7411B Software or Cal History Management Disk using the procedure described under Initializing The System. After the operator has completed this procedure, the Controller displays a system directory similar to that shown in Figure 2-14.

2. Press CTRL/T. (Press and hold down the CTRL key, then press the T key, case does not matter.) Then press CTRL/P. The controller will respond with the FDOS> prompt. Type TIME when you see this prompt.

3. Figure 2-15 shows the prompts that appear on the display and sample responses to these prompts. The responses are underlined.

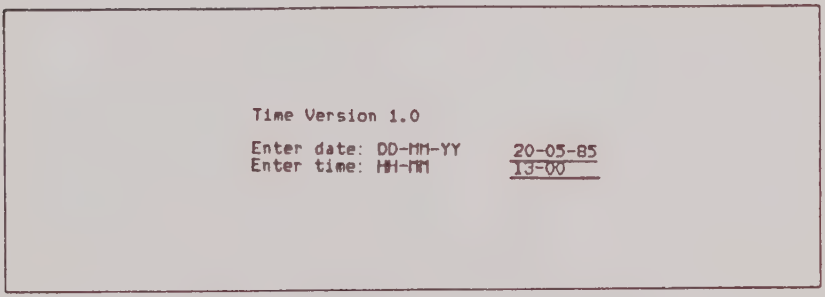


Figure 2-15. Prompting Messages for Date and Time

4. Enter the date. Use a space, dash(-), colon(:) or semicolon(;) to separate the day, month, and year. The System verifies that the date is valid. If an invalid date such as February 30 is entered, the System reprints the prompting message and allows the operator to enter the date again.

5. Enter the time. Observe that a 24-hour clock is used. A space, dash(-), colon(:) or semicolon(;) may be used to separate the hours and minutes. The System verifies that the entered time is valid. If an invalid time, such as 25:00 hours, is entered, the system reprints the prompting message and allows the operator to enter the time again.

6. After the date and time are entered, the System maintains them indefinitely unless the power is off for 90 days or more, or unless the single board computer of the Controller is removed.

7. The disk should not be in the disk drive. Press the RESTART button on the Controller. The Controller briefly displays the messages shown in Figures 2-10 and 2-11, then it displays the Program Recovery screen. To return to the main directory, you can press either the [Yes] or [Term] soft key.

Section 3
Operation Tutorial

INTRODUCTION

This section outlines a step-by-step approach to operating a 7411B-controlled System. It provides the operator with a thorough introduction to the automated calibration process. The Controller display keys are indicated by square brackets [ ] in the text. (The Operator's Aid keys are active; they perform the same function.)

It is essential that the operator understand the information in this section before continuing to Sections 4 and 5. This section is used in conjunction with Section 3 of the Procedure Writing Manual. The procedure used in this section is contained on the 7411B Procedure Disk, as well as on hard disk, if your 7411B system has been configured as a hard disk based system. For a hard disk based system the steps that relate to inserting a procedure disk can be skipped.

The example used in this section references two figures. Figure 3-1 illustrates the Tutorial Procedure as it would appear if the operator listed the procedure using List, Copy or Delete Data. Figure 3-2 illustrates how the results for this procedure might appear.

```
JOHN FLUKE MFG. CO., INC.                                    7411B PROCEDURE

********************************************************************************

INSTRUMENT:              Fluke 7404B Tutorial Procedure

DATE:                    10-Dec-84
REVISION:                2.0

ADJUSTMENT THRESHOLD:    70%

NUMBER OF TESTS:         6
NUMBER OF LINES:         42
CONFIGURATION:           Fluke 5100B

********************************************************************************

 STEP    FSC      RANGE NOMINAL      TOLERANCE      MOD1       MOD2 3    4   CON

 1.001   HEAD           (PRELIMINARY OPERATION)
 1.002   DRAW            7 78  8 78                100 25 50100
 1.003   DISP           Turn the meter ON[DRAW 25,90,F]
 1.004   SET            RANGE/FUNCTION: *
 1.005   RNG            200mV
 1.006   MESS           Connect a shorting jumper between the input terminals
 1.007   EVAL     DOES THE METER READ LESS THAN +/-00.1?
 2.001   HEAD           (DC VOLTAGE CALIBRATION)
 2.002   DISP           Remove the shorting jumper and connect test leads to
 2.002   DISP           the VOLT_OHM inputs of the meter.
 2.003   5100     200   190mV          .3V                                    2W
 2.004           5100   190mV                                            S    2W
 2.005           DISP   (Adjust R23) for a UUT reading of 190.0 mVDC
 2.006           JMP    2.003
 3.001   5100     2     1.9V           .3V                                    2W
 3.002           5100   2V                                               S    2W
 3.003           DISP   (Adjust R25) for a UUT reading of 1.9 VDC
 3.004           RPT
 4.001   5100     20    19V            .3V                                    2W
 5.001   5100     200   190V           .3V                                    2W
 6.001   5100     1200  1000V          2V                                     2W
END
```

Figure 3-1. 7411B Example Tutorial Procedure

JOHN FLUKE MFG. CO., INC. 7411B UUT RESULTS

****

UNIT UNDER TEST: Fluke 7404B Tutorial Procedure
SERIAL NUMBER: 0123456789
UUT CODE: Tutorial

RESULT: Pass
ADJUSTMENTS PERFORMED: 1
TEST STATUS: COMPLETED
OPERATOR: DEMO MODE
ELAPSED TIME: 35 Minutes
DATE: 14-Oct-84

****

TEST	RANGE	UUT INDICATED	SYSTEM ACTUAL	MODIFIER	ERROR (%TOL)
1	PRELIMINARY OPERATION				
1	OPERATOR EVALUATION				PASS
2	DC VOLTAGE CALIBRATION				
2	200	190mV	190.06		20
2	REMARK				
3	2	1.9V	3.1		400
3	ADJUST PERFORMED				
3	Adjust R25				
3	2	1.9V	1.9		0
4	20	19V	19		0
5	200	190V	190		0
6	1200	1000V	1000.2		10
END					

Figure 3-2. Tutorial Procedure Results

GETTING STARTED

The example requires a Fluke 1722A Instrument Controller with 512K RAM. Other system hardware is not necessary. To use the procedure on the system with a test meter, substitute step 5b for step 5a below. (Use either step 5a or 5b, not both.)

The following steps describe the startup procedure for the Operation Tutorial:

1. Verify that the Controller is operational.

2. If your 7411B system is configured as a floppy disk based system, insert the 7411B Calibration Software Disk 1, and press the RESTART button on the front panel of the Controller.

3. If your 7411B system is configured as a floppy disk based system, wait approximately 2 minutes while the disk loads. The Controller will prompt you to remove the disk and press [ADV]. If so requested, insert Calibration Software Disk 2 and press [ADV].

4. When the 7411B System Directory appears, select Enter New Operator Name.

5. If you are not actually testing a UUT for this tutorial, do Step a. If you are testing a UUT, do Step b:

   a. Using the TSO keyboard (or the 1722A keyboard) enter DEMO MODE, then press [ENTR] (or RETURN on the keyboard).

   b. Using the TSO Keyboard (or the 1722A keyboard) enter your name, then press [ENTR] (or RETURN on the keyboard).

6. Select Calibrate UUT.

7. If your 7411B system is configured as a floppy disk based system, insert the Procedure Disk, and press [ADV].

   The 1722A displays the procedure selection menu:

```
Procedure Names: _____________

    Manual entry of property number (in reverse video)
    Procedure_name_1                          UP
    Procedure_name_2
    Procedure_name_3                          DOWN
    Procedure_name_4
    Procedure_name_5                          SELECT
    Procedure_name_6
    Procedure_name_7                          RESELECT
    Procedure_name_8
    Procedure_name_9
    Procedure_name_11
    Procedure_name_11

    0 of xx     SELECT PROCEDURE OR USE BAR CODE READER
```

   On this menu listing you will notice the name of the Tutorial Procedure. Press the [DOWN] display key until the Tutorial Procedure appears in reverse video and then press [SELECT].

8. Press [NEXT] until the 7411B Tutorial Procedure appears, then press [YES].

9. If your 7411B system is configured as a floppy disk based system, wait approximately 20 second, while the procedure is transferred to RAM For a hard disk based system, the transfer occurs much faster.

ENTERING UUT SERIAL NUMBER AND CODE

Use the following procedure to enter the UUT serial number and code:

1. Using the TSO Keyboard (or the 1722A keyboard if installed) enter the UUT serial number and press [ENTR].

2. Using the TSO Keyboard (or the 1722A keyboard if installed) enter the UUT code and press [ENTR]. (The UUT Code can be any number that is associated with the instrument you are calibrating. This could be a company property number, asset number, or whatever you wish.)

NOTE:

In the 7411B system it is possible to select a procedure by entering a property number that has been entered into the Bar Code File, either manually or with a bar code reader. (See section 5 of the Procedure Writing Manual for details of using the "Edit Bar Code File" option.) For this tutorial we have assumed that you are not using the bar code feature.

PRELIMINARY OPERATION

The tutorial procedure instructs the operator to perform a series of preliminary operations (i.e., initial control settings, hook up, and ambient checks). Each instruction contains an illustration of the UUT along with a graphic locator to assist the operator in performing the indicated task.

The following steps demonstrate how you would begin a calibration procedure:

1. Turn the UUT on and press [ADV].

2. Set the UUT range and function controls to 200 mV dc, and press [ADV].

3. Connect a shorting jumper between the input terminals of the UUT, and press [ADV].

4. If the UUT display reads as instructed, press [YES]; otherwise, press [NO].

5. Remove the shorting jumper, and connect a test cable to the V-OHM input of the UUT. Press [ADV].

DC VOLTAGE CALIBRATION

The tutorial procedure includes a dc voltage calibration routine. Other procedures may contain a routine similar to the one presented. The system automatically produces range and connection messages. The procedure writer can defeat these messages; some of the Fluke example procedures give the operator the choice of including the messages.

Connect the UUT to the port as instructed by the message on the Controller display, then press [ADV]. (In the 7404B the port is a 5100B Calibrator, in the A123 the port is a dV Calibrator, and in the 7405A the port is multifunction.)

ADJUSTING THE SYSTEM STIMULUS

At this point in the procedure, the system supplies a stimulus to the UUT. The first stimulus is 190 mV on the 200 mV range of the UUT. Therefore, the system asks the operator to adjust the system stimulus for a UUT reading of 190 mV.

The following step shows how you adjust the system stimulus using the [L/\] [S/\] and [L\/] [S\/] keys:

1. Press [S/\] twice, then press [ADV].

POST-TEST SUMMARY

A Post-Test Summary appears after every test (if the procedure writer has not defeated this feature). Some of the Fluke example procedures give the operator the choice of viewing the Post-Test Summary. The system lists the test number, the UUT range, the value that the UUT indicated, the stimulus that the system had to provide to make the UUT read the proper value, the frequency of the test, and the UUT error. (As a percent of the allowable tolerance, 100% is a UUT failure.)

The Post-Test Summary also provides the operator with several options. These options are described below:

- [REM] allows the operator to enter a remark, using the TSO or keyboard.
- [LIST] lists the calibration procedure on the screen. (This option can be defeated by the procedure writer.)
- [STEP] displays the UUT setup for the current step. (Setups are stored via the SET Function Selection Code. You can find more information in the description of the SET FSC in the 7411B Procedure Writing Manual.)
- [ADV] advances control to the next step.
- [REP] repeats the last step.
- [TERM] terminates the procedure entirely. (This option can be defeated by the procedure writer.)

The following steps demonstrate how you might exercise the options of the Post-Test Summary:

1. Press [REM].

2. Enter a remark, and press [ENTR].

3. Press [LIST].

4. Observe the procedure by pressing [LAST] or [NEXT] to change pages.

5. Press [TERM]. (Pressing [TERM] from the procedure list display returns control to the Post-Test Summary.)

6. Press [STEP].

7. Observe the current UUT setup (if any SETs have been stored), and press [ADV].

8. Press [ADV] to advance to the next test.

9. Set the UUT to the 2V range, and press [ADV].

TEST FAILURE AND CALIBRATION ADJUSTMENT

When a particular test fails to meet specifications, the operator may adjust the instrument (if the procedure writer has included the adjustment procedure). Some of the Fluke Example Procedures have mandatory calibration adjustments when a test error exceeds the adjustment threshold.

The following steps demonstrate an example adjustment included in the tutorial procedure:

1. Press [L/\] four times (this causes the test to fail) then press [ADV].

2. Note that the error field flashes, and the FAIL indication appears. There is a calibration adjustment routine for this test because the [ADJ] display key appears.

3. Press [ADJ] to adjust the instrument.

4. Adjust the indicated control as directed by the System.

5. Press [ADV] to repeat the failed test.

6. Press [ADV]. (The instrument was just adjusted, so no slewing should be necessary.)

7. Observe the Post-Test Summary, and press [ADV].

CONTINUING WITH DC VOLTAGE CALIBRATION

Use the following steps to continue the vertical deflection calibration:

1. Set the UUT to the 20V range, and press [ADV].

2. Adjust the system stimulus, if necessary, and press [ADV].

3. Observe the Post-Test Summary, and press [ADV].

4. Set the UUT to the 200V range, and press [ADV].

5. Adjust the system stimulus, if necessary, and press [ADV].

6. Observe the Post-Test Summary, and press [ADV].

7. Set the UUT to the 1200V range, and press [ADV].

8. Adjust the system stimulus, if necessary, and press [ADV].

9. Observe the Post-Test Summary, and press [ADV].

PROCEDURE TERMINATION AND RESULTS OPTIONS

The procedure is finished when either [TERM] is pressed from a Post-Test Summary or the last test is performed. The system asks the operator to remove connections and then displays the results options. The results menu is as shown in Figure 3-3.

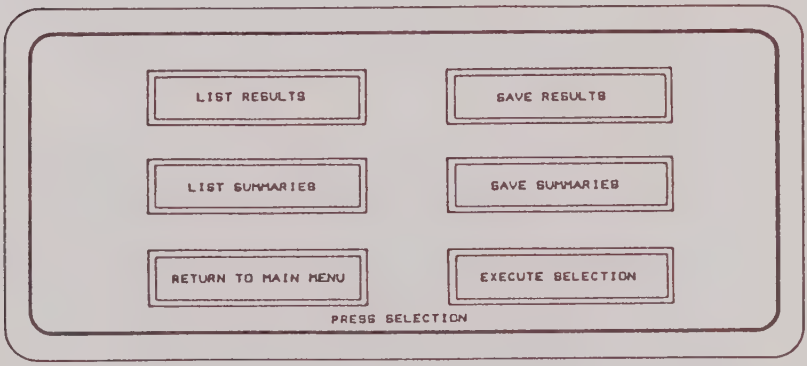


Figure 3-3. Results Menu

On this menu select [LIST RESULTS] and press [EXECUTE SELECTION]. A menu for a list device is displayed. This menu is shown in Figure 3-4. Press [SCREEN] on the Listing Device Menu. Note that the UUT results are printed on the screen.

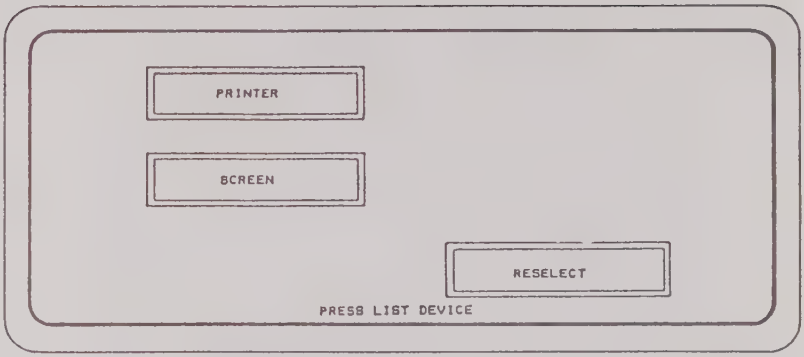


Figure 3-4. Listing Device Menu

UUT RESULTS LISTING

The UUT results listing appears in Figure 3-2. The heading contains the UUT name, serial number, and code. The heading also lists whether the instrument passed or failed, how many adjustments were performed, whether the tests were all completed, and the operator's name. The elapsed time and the date are also included. The results of each test are listed in a table. Both pre-adjustment and post-adjustment results are included.

The following steps demonstrate how to obtain the UUT results listing:

1. Observe the first page of the calibration results. Note the heading information.

2. Press [ADV].

3. Observe the second page of the calibration results. Note the end of the heading and the test results column titles.

4. Press [ADV].

5. Observe the third page of the calibration results. Note that test number 3 includes the pre-adjustment results, an indication that an adjustment was performed, and the post-adjustment results. The words ADJUST PERFORMED were added by the system automatically.

6. Press [ADV].

7. Observe the last page of the calibration results, and press [ADV].

SAVING CALIBRATION RESULTS ON A DISK

The calibration results may be saved on disk, as described in the following procedure. The floppy disks, if used for this purpose, are called "Calibration Results Disks".

The following procedure demonstrates how to save results to the Calibration Results Disk (for a Floppy Disk System) or the Hard Disk (for a Hard Disk System).

1. In the Results menu select [SAVE RESULTS] and press [EXECUTE SELECTION].

2. When prompted for inserting a Calibration Results Disk in the floppy disk drive, do so (only in the case of a Floppy Disk System).

3. Press [ADV]. The results are now automatically transferred to the disk. This step is only needed in the case of a Floppy Disk System.

For the purpose of calibration history management, only a summary of each calibration need be saved on the Calibration Results Disk. The operator may save all of the results if records of the individual tests are desired.

In the 7411B system, Cal History Management will only operate on result files stored on floppy disk. As the Save Device menu shows, in the case of a Hard Disk System, results are always stored on hard disk. Those results must be copied to floppy disk (using the Copy Utility in the List, Copy or Delete menu) before Calibration History can operate on them. There are other industry standard database management software package available, which can be used; the Fluke 7411B-500 software provides an interface between the 7411B calibration system and the IBM-PC.

RETURNING TO THE SYSTEM DIRECTORY

Now that the results are saved (if you opted to do so), the operator may return to the system directory to begin another calibration. To return to the system directory, perform the following steps:

1. Select [RETURN TO MAIN MENU].

2. Press [EXECUTE SELECTION].

3. The System Directory should now be displayed on the 1722A screen.

Section 4
System Software Overview

INTRODUCTION

The operator should read the first three sections of this manual before proceeding with this section of the manual.

The operator uses two or three floppy disks during calibration of an instrument if his 7411B system is configured as a floppy disk based system. In a floppy disk based system, the 7411B Calibration Software Disk 1 is loaded first. Read Calibration Software Disk 2, if needed. Then the Procedure Disk can be read. The Procedure disk contains the specific procedure for the instrument being calibrated. After the calibration is complete, a fourth disk may be used for results storage.

The 7411B System Software displays the system directory when it is first loaded. Selections may be made from this directory.

7411B SYSTEM SOFTWARE SYSTEM DIRECTORY

Figure 4-1 shows an example of a 7411B System Software Directory. The following paragraphs provide a brief description of each selection from this directory.

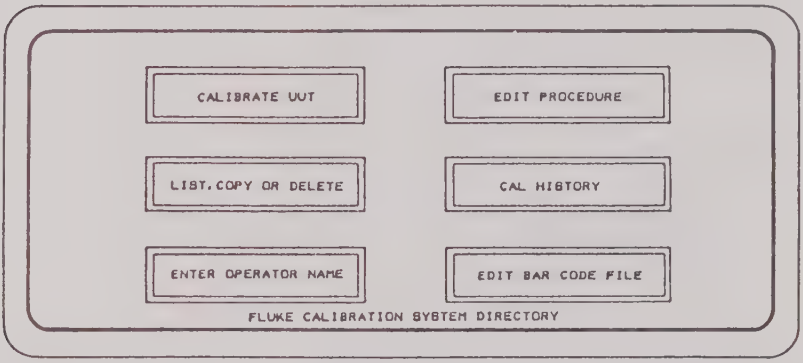


Figure 4-1. Instrument Calibration Directory

Calibrate an Instrument

This selection allows the operator to calibrate an instrument. Section 3 contains a description of this process, and Section 5 contains a detailed discussion of this selection.

After selecting **'[ ] CALIBRATE UUT'** from the **'Calibration System Directory'** (Figure 4-1 Instrument Calibration Directory) the 7411B polls the instruments it has been configured to use for instrument calibration to determine if they are active on the IEEE-488 bus. If an instrument fails to respond to the poll, the 7411B treats it as being missing from the IEEE-488 bus, and the following screen will appear (for this example, it is assumed that an 8506A is missing).

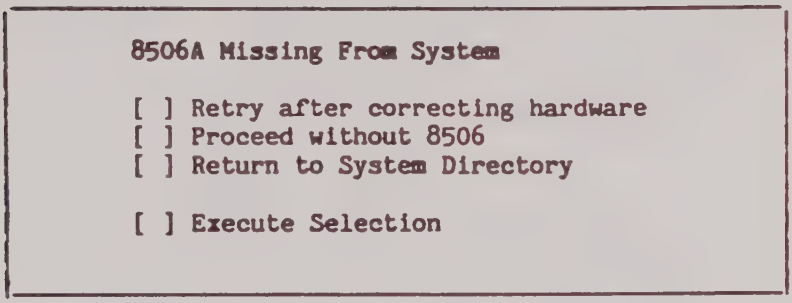

8506A Missing From System
[ ] Retry after correcting hardware
[ ] Proceed without 8506
[ ] Return to System Directory
[ ] Execute Selection

Figure 4-2. Missing Instrument Display

The operator should make one of these choices. If, in this example, the operator chooses to **'[X] Proceed without 8506'** the system will operate without the 8506A until it is rebooted from the 7411B's Instrument Calibration diskette. A procedure that needs to use the missing instrument (e.g. the 8506A) will generate an error message when the instrument is needed. Errors are discussed on pages 5-26 through 5-30 of this manual.

List, Copy, or Delete

This selection allows the operator to list, copy, or delete procedures and results. Section 6 discusses this selection in detail.

Enter New Operator Name

This selection allows the operator to enter a name which will then appear on the test results. The name may include letters, numbers, symbols, and embedded blanks. If the operator enters DEMO MODE instead of a name, the system will execute procedures without any

system hardware other than the 1722A. The DEMO MODE may be used for initial procedure checkout. If a name has been previously entered, it will be displayed on the entry line. To preserve this name, simply press ENTR. To change the name, pressing any non-ENTR key will begin entry of a new operator name.

Edit a Procedure

This selection allows the procedure writer to write a new calibration procedure, modify an existing procedure, or create a new procedure from an existing procedure. This selection requires the use of the 1722A Keyboard (which should be disconnected during calibration). Refer to the Procedure Writing Manual to write or modify a procedure.

Cal History (Optional)

The Cal History Management Option allows the operator to access the Cal History Management data package.

The Cal History Management disk must be loaded into the Controller after the 7411B System Software has finished loading. (When the Remove Disk From Drive prompt appears, remove the 7411B System Software disk, insert the Cal History Management disk, and press [MGT] on the controller display.) Once the Cal History Management disk is loaded, it appears on the System Directory Menu. Selecting this option causes the Cal History Management menu to appear.

Even if your 7411B has been configured as a hard disk based system, the Calibration History Management software can only operate on result files on floppy disk. This procedure enforces back up of results on floppy disk and avoid potentially serious consequences caused by hard disk crashes.

Edit Bar Code File

The Bar Code File in the system contains the bar codes or property codes known to the 7411B system. Each property code entry in the file includes that UUT's serial number, and the name of the appropriate calibration procedure. The Edit Bar Code File option lets you add or delete bar codes to be recognized by the 7411B software.

When you use the bar code option to initiate a calibration procedure, you do not have to enter serial number and UUT (property) code. If your system is configured as a floppy disk based system, you will be prompted to insert the floppy disk containing the bar code files.

Refer to Section 5 of the 7411B Procedure Writing Manual for detailed instructions for adding or deleting property codes in the Bar Code File.

FORMATTING A NEW PROCEDURE AND RESULTS DISK

Procedures and results are stored on disks that have been formatted by using the Controller's File Utility Program (FUP). Once the disk is formatted, the operator may reenter the system directory by pressing the RESTART button on the front of the Controller. Disks used for results or procedures should not contain an operating system (i.e., FDOS.SYS). If they do, the power-fail restart mechanism does not work properly. Results disks (when formatted) may contain results, procedures, or BASIC programs.

The following procedure demonstrates how to format a Results disk using FUP:

CAUTION

Formatting disks that contain procedures, results, or programs, will cause that information (on the previously formatted disk) to be erased. No recovery of lost data is possible.

1. While the Fluke Calibration System Directory is displayed, press CTRL/T. (Press and hold down the CTRL key, then press the T key.) This action clears the screen and activates the keyboard. Next, press CTRL/P. This action causes the System to return control to the 1722A Console Monitor (FDOS). (Refer to the 1722A System Guide for a description and uses of the Console Monitor).

2. Enter FUP <RETURN> to transfer control to the File Utility Program (FUP).

3. Insert the a disk and enter MF0:/F2 <RETURN>. FUP will then ask for a verification of intention. (The Results disk and the Procedure disk should have more than 1 directory segment on them.)

4. Read the displayed warning and enter a Y (yes) <RETURN>.

NOTE:

Once Y (yes) is entered, the contents of the disk (if any) are destroyed.

5. When the operation is complete (FUP will respond with FUP>), you can scan the disk for bad blocks. Scanning is accomplished by entering MF0:/S <RETURN>. FUP should respond with a statement that there are zero bad blocks.

How the 7411B Directory Structure Works

The 7411B uses a directory structure to accommodate long file names. The directory structure is like an ordinary telephone book: the long file names are the names of the telephone subscribers and the telephone number is the actual name of the file that is represented by the long file name. This means that on each mass storage device (a floppy disk or hard disk) there must be a file containing the directory structure. If there is no directory structure on the disk, the 7411B system will not be able to read any files from that disk memory. If an attempt is made to write to a floppy disk that doesn't have a directory structure file, the 7411B system will automatically create one.

Using 7411A Procedures in the 7411B System

Floppy disks containing procedure files that were created using a 7411A system need to be re-formatted using a special program delivered with the 7411B system. Refer to the 7411B Configuration Manual for more information. The same procedures that ran on the 7411A system will also run on the 7411B system.

Section 5
How to Calibrate an Instrument or Device

INTRODUCTION

This section explains how to use the 7411B to calibrate an instrument or device. The operator should be completely familiar with the concepts presented in the earlier sections of this manual before using the material in this section.

Calibration

Calibration is the act of stating or determining that an instrument or device meets its published or required specifications. A computer-aided calibration system calibrates instruments and devices by executing procedures consisting of a series of performance tests of specific functions of the instrument or device at particular points. These procedures may or may not include adjustment messages. The adjustment messages, if included, may be displayed when a performance test fails or exceeds its Adjustment Threshold.

The 7411B employs the same basic method to calibrate any instrument or device. First, for a measurement-type UUT, the system generates an accurately known stimulus. Then the 7411B will allow you to increase or decrease the stimulus until the instrument displays the specified value.

The operator increases or decreases the value of the stimulus using the display keys of the Controller's screen or by using the corresponding buttons on the Operator's Aid. This process of increasing or decreasing the stimulus is called slewing. The details of this operation will be discussed later. After slewing, the actual value of the stimulus may be higher or lower than the nominal value displayed by the instrument.

After the operator adjusts the stimulus so that the instrument displays the nominal value, the system computes the difference between the actual value of the stimulus and the nominal value displayed by the instrument. This difference is compared with the tolerance specified for the instrument to determine if the instrument passed or failed the test.

If the instrument error (% of Tol) exceeds the Adjustment Threshold and adjustment messages have been included in the procedure, the operator is given the option of displaying these messages and making adjustments to the instrument. Adjustment procedures might also be mandatory.

When the last test has been performed, the system allows the operator to display the results on the Controller screen, print the results on the printer, save the results on a disk, or transmit the results to another computer.

PROCEDURE SELECTION

The following paragraphs describe the first steps of calibrating an instrument. These steps entail selecting and loading the procedure, selecting the instrument to be calibrated, and executing the calibration procedure.

Loading the Procedure

When you select [CALIBRATE] [UUT] in the Fluke Calibration System Directory (the Main Menu) in a hard disk based system, the 1722A screen quickly displays a list of procedures. In a floppy disk based system, first you are prompted to insert the Calibration Procedures Disk, then the 1722A screen displays a list of procedures.

Figure 5-1 shows an example:

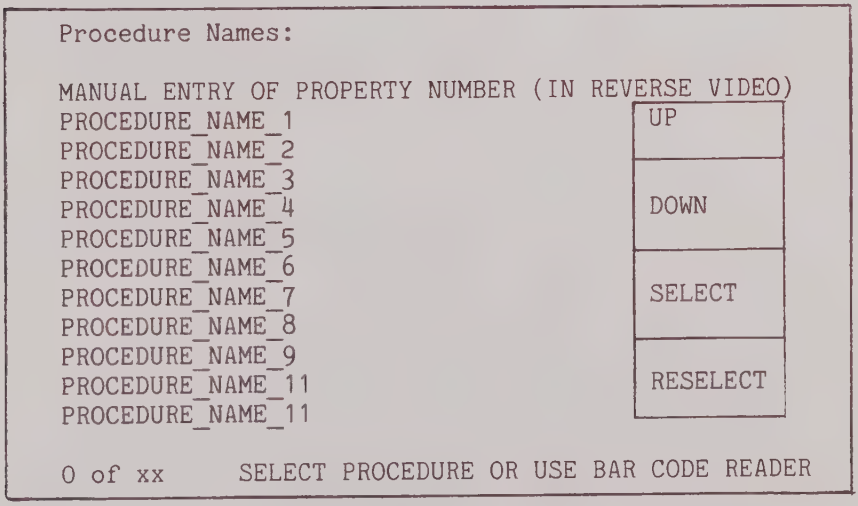


Figure 5-1. Procedure Selection Menu

In the Procedure Selection Menu, the first entry "MANUAL ENTRY OF PROPERTY NUMBER" is displayed in reverse video. Following it are the next 11 calibration procedure names on the disk. At the lower left the indication "0 of xx", for example 0 of 21, indicates that there are a total of 21 procedure names on the disk. (The Manual Entry of a Property number does not represent an actual procedure, therefore when the reverse video block is on this line, the first number in the lower left corner is 0.) The index is useful to the operator to see where he is in the listing of calibration procedure names. The operator cannot rely on having these procedures always being in the same order when additions or deletions are made to calibration procedures. If no changes are made, however, the procedures will always appear in the same order.

A prompt on the last line of the display identifies the action that the operator has to take; in this case he needs to select a procedure in one of three ways:

- Using a bar code reader
- By entering the property code manually
- Using the [UP] or [DOWN] keys followed by [SELECT]

These three methods of selecting a procedure are described in detail under the headings, "Using a Bar Code Reader", "Manually Entering Property Code", and "Direct Selection of the Calibration Procedure", but presented first are descriptions of the functions of the display keys on the Procedure Selection Menu.

On the right side of the screen you will note four display keys labeled [UP], [DOWN], [SELECT], and [RESELECT]. The next paragraphs describe the function of these display keys.

The [DOWN] display key the highlighted block down through the listing of calibration procedures. When the highlighted block reaches the bottom of the screen, pressing the [DOWN] display key displays the next 12 procedure names in the directory. When the highlighted block reaches the last entry in the directory, pressing the [DOWN] display key again displays the "MANUAL ENTRY OF PROPERTY NUMBER" entry, and the first 11 procedures again, allowing you to scroll in a loop through all the procedures.

The [UP] display key does the same thing as the [DOWN] display key, but in the other direction. The [UP] display key scrolls the highlighted block up through the listing of calibration procedures. When the highlighted block reaches the top of the screen, pressing the [UP] display key again displays the previous 12 procedure names in the directory. When the highlighted block reaches the first procedure listing, "MANUAL ENTRY OF PROPERTY NUMBER", pressing the [UP] display key again displays the very last group of calibration procedures in the directory, allowing you to scroll in a loop through all the procedures.

You may keep your finger on the [UP] or [DOWN] display key to scroll quickly through the listing of calibration procedures, 12 at a time. Each set of 12 procedure names is displayed long enough for you to glance at them and stop at that point if you wish to.

Pressing the [RESELECT] display key returns control to the Fluke Calibration System Directory from the Calibration Procedure selection menu without starting a calibration procedure.

LOADING USING A BAR CODE READER

To select a procedure with using a bar code reader, you simply wave the bar code reader wand across the bar code sticker on the UUT. (It does not matter where on the screen the highlighted block is positioned.)

After the bar code reader reads the UUT's bar code, the 1722A display indicates that the desired procedure is being transferred from the system disk medium to E-disk. Then the calibration procedure then starts up without prompts to enter serial number and property code of the UUT. (The serial number and correct procedure name for the UUT are retrieved by the system from the Bar Code File. The UUT property code is the number read by the bar code reader.)

LOADING BY MANUALLY ENTERING THE UUT PROPERTY CODE

This option is useful if the operator does not have a bar code reader available to him, but still would like to take advantage of calibration procedure selection through the use of property codes.

The Procedure Selection menu shows the entry "MANUAL ENTRY OF PROPERTY CODE" in reverse video when the menu is first displayed. If you select this menu choice by pressing the [SELECT] display key, the 1722A screen displays an alphanumeric keyboard as shown in Figure 5-2. You can use this keyboard to manually enter the property code of the UUT.

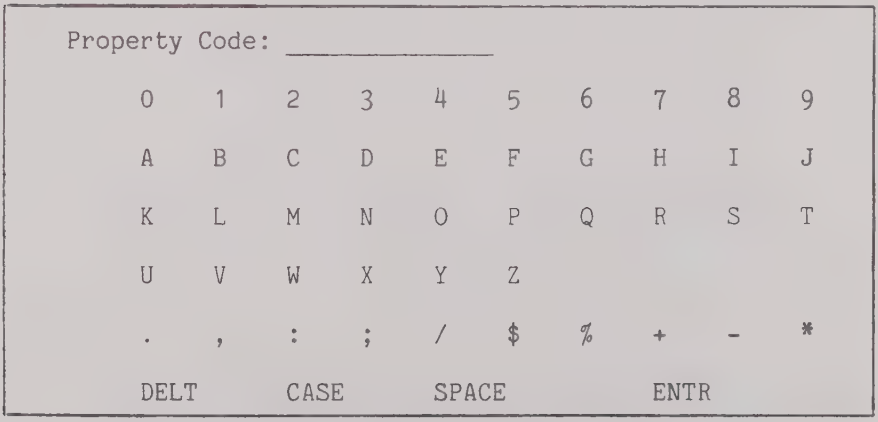


Figure 5-2. Alphanumeric Keyboard Screen to enter property code

After you enter the property code either by touching the appropriate characters on the screen followed by [ENTR], or by typing the characters on the 1722A keyboard, the calibration procedure is loaded and run automatically. The serial number and property code of the UUT are entered automatically from the Bar Code file at the same time.

LOADING BY DIRECT SELECTION

Move the reverse-video block up or down by pressing the [UP] or [DOWN] display key until it covers the desired procedure name. Press the SELECT display key to select the highlighted procedure. This loads the procedure in the memory of the 1722A for execution. With this method of procedure selection, the operator will get prompts to enter the serial number of the UUT and the UUT code.

After you select a procedure name with the [SELECT] display key, the 1722A displays an alphanumeric keyboard that you can use to enter the UUT serial number and UUT property code. (You can use either the keyboard showing on the display or the 1722A keyboard if it is installed.) The UUT serial number is the unique number assigned by the manufacturer to identify a particular instrument. It is usually inscribed on the instrument itself.

The UUT code is chosen to meet the needs and requirements of individual facilities. The code might for example, represent an assigned property number.

Entry of these items is optional. If entered, this information will be stored and printed with the test results. If you do not wish to enter this information, selecting [ENTER] with no data allows the system to proceed to the next step.

Again, if a Bar Code reader is used or the property code is entered manually, the entries for UUT serial number and UUT code are made automatically from the contents of the Bar Code file.

Executing the Procedure

Execution of the procedure begins after the UUT serial number and UUT code have been entered. The details of each procedure are different just as each individual instrument is different. All procedures, however, follow the same pattern. There may be an initial setup message describing the UUT warm-up time, ambient (room) temperature, and other specifications required to ensure proper calibration. The procedure may then inform the operator how to set up the UUT for calibration.

The main body of the procedure consists of a number of calibration tests that check the performance of the UUT at specified cardinal points. These calibration tests may consist of electrical performance tests, or they may be in the form of a question to the operator.

Graphic Locator

The graphic locator assists the operator with settings, adjustments, and connections. The locator consists of an image of the UUT along with a flashing indicator. The image may represent any side of the UUT, or it may display a certain plug-in, board, etc. Graphic locators are included at the option of the procedure writer.

Making Connections

WARNING

THE POTENTIAL FOR ELECTRICAL SHOCK HAZARD MAY BE PRESENT AT THE TERMINALS OF THE SYSTEM DURING PROCEDURE EXECUTION. CAREFULLY FOLLOW ALL CONNECTION AND DISCONNECTION MESSAGES PRODUCED BY THE SYSTEM.

CONNECTIONS

As the procedure is executed, the system displays messages instructing the operator to connect and disconnect test cables between the instruments of the system and the UUT. These messages are automatically produced by the system.

Figure 5-3 is an example of the standard connection message. In this example the operator would connect the test leads from the UUT to the 5100B output port on the system and then touch [ADV.] Alternatively, the operator could touch [TERM] to terminate the calibration test.

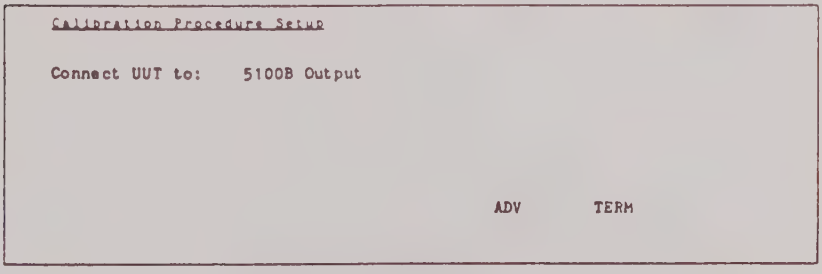


Figure 5-3. Standard Connection Message

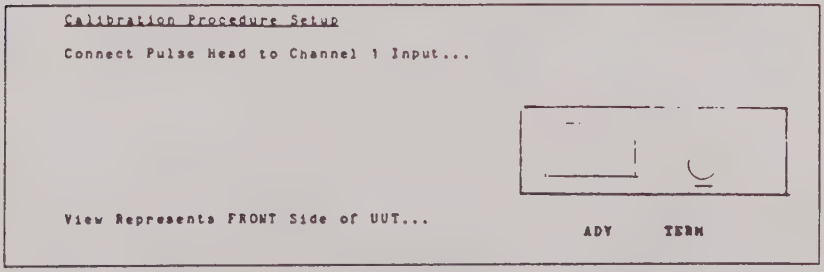


Figure 5-4. Courtesy Connection Message

The standard connection message shown in Figure 5-3 does not specify in detail how to make the connection of the test lead at the UUT end. The procedure writer may include a courtesy message (shown in Figure 5-4) specifying precisely where the test leads are to be connected on the UUT. These courtesy messages, however, are optional, and may be omitted in procedures written for experienced operators.

Typically, when a courtesy message is included, it instructs the operator to connect one end of the test lead to the UUT. The courtesy message is followed by a standard connection message instructing the operator to connect the other end of the test lead to a specific instrument terminal. Courtesy messages, however, depend on how the procedure has been written and may vary.

DISCONNECTIONS

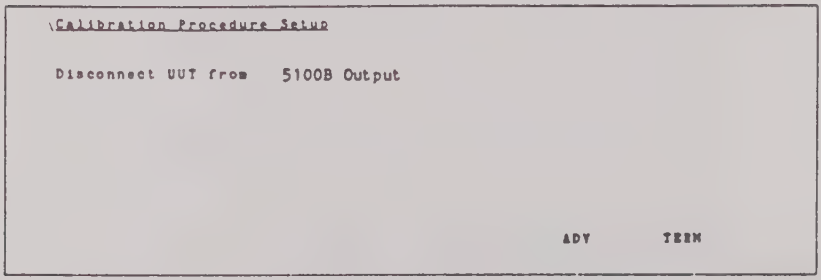


Figure 5-5. Disconnection Message

The system also displays messages similar to the one shown in Figure 5-5 instructing the operator to disconnect the test leads after the test has been performed.

Adjusting the Stimulus or Display

The typical calibration test requires adjusting the stimulus until the UUT reads a certain value or adjusting the display to match the value indicated. Figure 5-6 shows an example of the Adjust Stimulus Display. This display allows the operator to increase or decrease the stimulus by touching the appropriate display keys. See Table 5-1. (Table 5-1 applies only to the Adjust Stimulus and the Match UUT Displays. The display keys presented in Table 5-1 perform different functions in other displays.)

Table 5-1. Adjust Stimulus/Match UUT Display Keys

DISPLAY KEY	ACTION
TEST	The number of the test. If the number is hyphenated, then the first number is the test from which a subprocedure was called, and the second number is the subprocedure test number.
RANGE	The UUT Range being tested (in the units of the UUT indicated).
UUT INDICATED	The nominal value of the stimulus provided by the UUT or the nominal value measured by the UUT.
SYSTEM ACTUAL	The actual value of the stimulus provided by the Automated Calibration System, or the actual value measured by the Automated Calibration System, (in the units of the UUT indicated).
MODIFIER	Additional attributes of the stimulus or measurement. For example, the modifier for ac volts would be the frequency.
ERROR (%TOL)	The variance between the value indicated by the UUT (UUT indicated) and the value indicated by the system (SYSTEM ACTUAL) compared to the allowable tolerance specified by the procedure writer. This variance is computed as a percentage of the allowable tolerance.

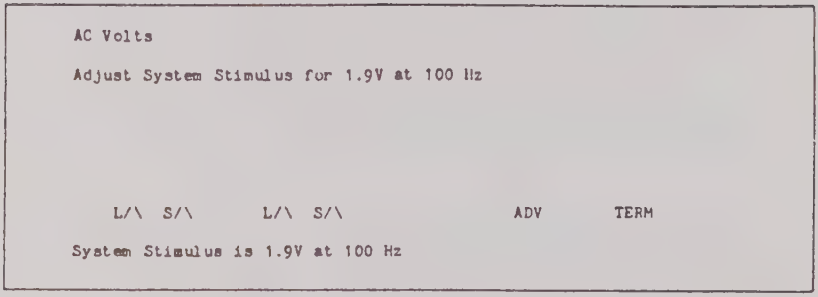


Figure 5-6. Adjust Stimulus Display

The operator presses [ADV] when the UUT reads the nominal value presented on the Adjust Stimulus Display. The system then presents the Test Results Display similar to the one shown in Figure 5-7. Alternatively, the operator may press [TERM] to terminate the test. This action causes the system to display the Calibration Results Display showing that the test was terminated by the operator. Procedures may be written so that the system does not stop at the Test Results Display.

AC Volts Accuracy

TEST	RANGE	UUT INDICATED	SYSTEM ACTUAL	MODIFIER	ERROR (%TOL)
25	2	1.9V	1.9	1KH	0

ADJ REM LIST STEP ADV REP TERM

Figure 5-7. Test Results Display

In some cases it is not possible to adjust the stimulus so that the UUT reads the nominal value exactly. When this occurs, the operator adjusts the stimulus (or display) so that the difference between the stimulus and the UUT reading is as small as possible.

CALIBRATION TEST RESULTS

The 7411B displays the calibration test results after each calibration test. Figure 5-7 shows a sample Calibration Test Results Display with all of the display keys. The display keys actually presented on a particular Calibration Test Results Display depend on how the procedure has been written. (The Procedure Writing Manual explains in detail how to write procedures.) Consequently, a specific Calibration Test Results Display may not contain all of the display keys shown in Figure 5-7. For example, the [ADJ] key will not appear on the display unless the procedure writer included adjustment instructions in the procedure and the calibration test results exceed the Adjustment Threshold. The [TERM] and [LIST] display keys may also be suppressed by the procedure writer in certain cases. Table 5-2 describes the column headings. Table 5-3 summarizes the action performed by each display key.

Table 5-2. Test Results Display Column Headings

DISPLAY KEY	ACTION
L▲	Increases the stimulus by a large amount (approximately equal to the allowable tolerance).
S▲	Increases the stimulus by a small amount (approximately equal to one tenth of the large amount).
L▼	Decreases the stimulus by a large amount (approximately equal to the allowable tolerance).
S▼	Decreases the stimulus by a small amount (approximately equal to one tenth of the large amount).
ADV	Computes and displays the test results.
TERM	Terminates the test. The system presents the test results display with the message Operator Terminated.

Table 5-3. Test Results Display Optional Keys

DISPLAY KEY	ACTION
ADJ	Displayed only when the adjustment threshold as listed in the procedure heading is exceeded and an adjustment procedure has been written for that test. Causes the system to display adjustment instructions.
REM	Allows a remark of up to 32 characters to be entered using the Alphanumeric Keyboard Display. (See the Alphanumeric Keyboard Display in Section 2). This remark will be displayed or printed with the test results
LIST	Lists the procedure This option is discussed under the heading Listing the Procedure.
ADV	Advances to the next test.
REP	Repeats the present test step
TERM	Terminates calibration execution. The system displays the List/Save Menu shown in Figure 4-16.
STEP	Displays the last 18 settings for the UUT. This option allows the operator to verify that the UUT is set up correctly for the current test

EXAMPLE: PERFORMING A CALIBRATION TEST

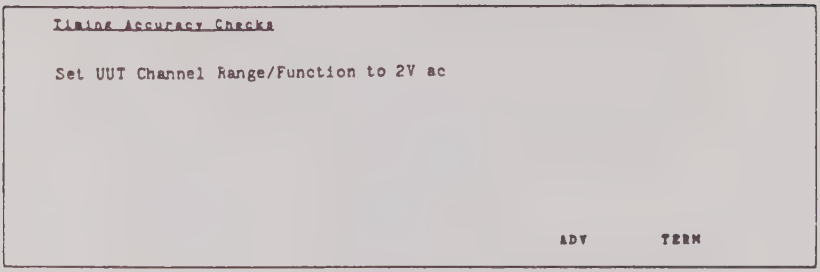


Figure 5-8. Range/Function Message

The following example shows the steps in a typical calibration test:

1. The system displays a connection message similar to the one shown in Figure 5-3. The operator makes the connections and presses [ADV]. (In some cases the required connection will already exist from the previous test and this step will be skipped.)

2. The system displays a message similar to the one shown in Figure 5-8 instructing the operator to set the UUT to the appropriate range and function. (In some cases the required UUT range/function will be set in a previous test and this step will be skipped.)

3. The system presents the Adjust Stimulus display similar to Figure 5-6 instructing the operator to adjust the stimulus until the UUT reads a certain value. In this case, the operator adjusts the stimulus by touching the display keys [L /\] (large up), [S /\] (small up), [L \/] (large down), and [S \/] (small down). Press [ADV] when the values correspond.

4. The system presents the Calibration Test Results Display similar to the one shown in Figure 5-9. In the example, the UUT passed the calibration test. Press [ADV] to proceed to the next test.

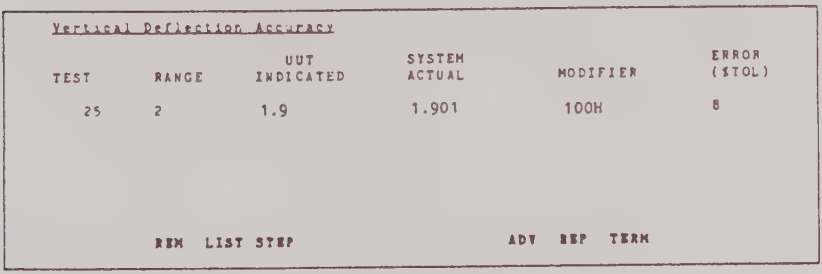


Figure 5-9. Test Results (Passed) Display

ADJUSTING THE UUT

The 7411B allows the UUT adjustment messages to be displayed when a calibration test fails. The adjustment messages contain the directions for adjusting the UUT so that it meets its performance specifications. Whether or not these messages are displayed depends on the particular instrument or device being calibrated and how the procedure has been written. Figure 5-10 shows a sample adjustment message from a procedure.

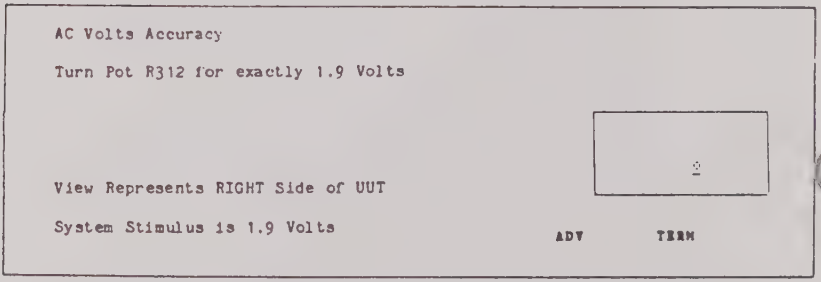


Figure 5-10. Sample Adjustment Message

EXAMPLE: TEST REQUIRING ADJUSTMENT OF THE UUT

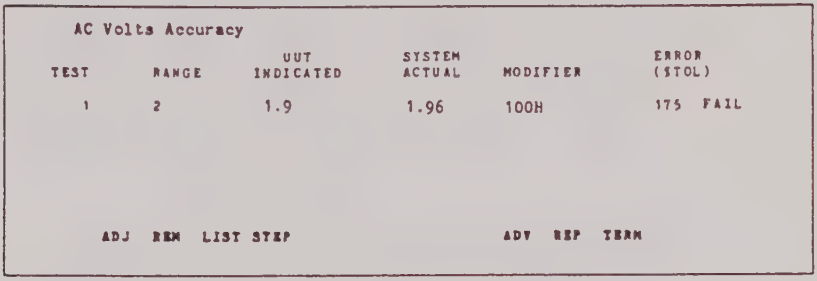


Figure 5-11. Test Results (Failed) Display

The following example shows the steps in a calibration test requiring UUT adjustment.

1. The system displays a connection message similar to the one shown in Figure 5-3. The operator makes the connections and presses [ADV]. (In some cases the required connection will already exist from the previous test and this step may be skipped.)

2. The system displays a message similar to the one shown in Figure 5-8 instructing the operator to set the UUT range and function. Again, the operator sets the UUT to the appropriate range.

3. The system displays a message similar to the one shown in Figure 5-6 instructing the operator to adjust the stimulus or, in some cases, the display.

4. The system displays the results of the calibration test. Figure 5-11 shows a sample calibration results display. In this example the UUT has failed the test. The system shows the UUT error is 175 percent of the allowable tolerance and displays the word FAIL. Since the UUT has exceeded the Adjustment Threshold, the [ADJ] display key is presented. The operator presses [ADJ] to adjust the UUT.

5. The system displays messages similar to the examples shown in Figures 5-12 and 5-13 instructing the operator to adjust the UUT.

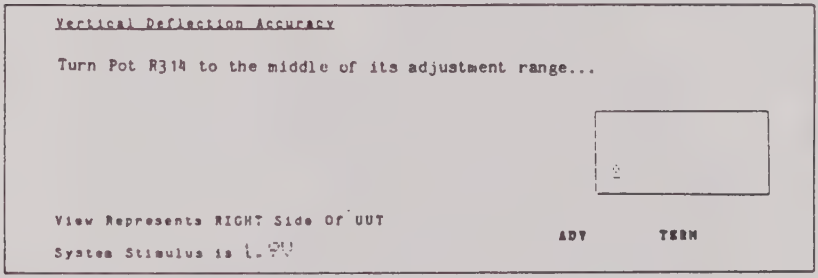

Vertical Deflection Accuracy
Turn Pot R314 to the middle of its adjustment range...
View Represents RIGHT Side Of UUT
ADJ
TERM

Figure 5-12. First Adjustment Message

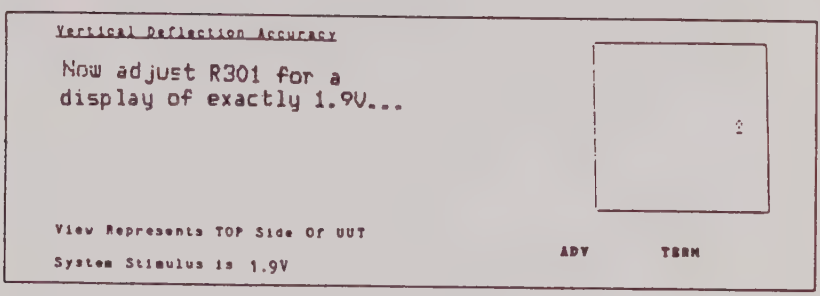


Figure 5-13. Second Adjustment Message

6. After the adjustments have been performed, the system continues as dictated by the procedure writer. Normally, the test that failed is repeated.

LISTING THE PROCEDURE

```
1.001 DISP      Allow the instrument to stabilize and test it at an
1.001 DISP      ambient temperature of 23 +/- 5 degrees Celsius.
1.002 DISP      In this procedure "Lo Ohms Test Lead" is a good SHORT.
1.003 HEAD      (DISPLAY TEST)
1.004 DISP      SET THE 8010A/8012A POWER switch to the ON position
1.005 DISP      Select Range/Function 2000 kOhms
1.006 EVAL   (IS THE OVERANGE INDICATION ILLUMINATED?)
2.001 DISP      Select the V function
2.002 EVAL   (DOES THE LCD DISPLAY 0007)
3.001 DISP      Connect the Lo Ohms  calibration lead between the V/kOhms
3.001 DISP      and COMMON input terminals.

      LAST  NEXT          UP  DOWN              ADV          TERM
```

Figure 5-14. List Procedure Display

The [LIST] display key may or may not appear, depending on how the procedure has been written. Pressing [LIST] causes the system to list the calibration procedure.

The example procedure in Figure 5-14 shows how a procedure appears on the Controller's screen. The line numbers on the left of each procedure line indicate the test number and the step within the test. The digits on the left of the decimal point indicate the test number. The digits on the right of the decimal point indicate the step within the test.

Since the procedure typically contains more lines than can be listed on the Controller's screen at one time, the procedure is divided into pages that are displayed one at a time. The [LAST] and [NEXT] display keys allow the operator to display the last page or the next page. Pressing [LAST] when the last page of the procedure is displayed causes the first page of the procedure to be displayed. The Operator's Aid buttons Lg /\ and Lg \/ may also be used to scroll through the procedure.

One line of the procedure is highlighted. Initially, when the procedure is displayed, the line that was being executed is highlighted. The operator can shift the highlight to different lines by pressing [UP] or [DOWN]. When a new page is displayed, as a result of the Last or Next command, the first line on the page is highlighted. The Operator's Aid buttons Sm /\ and Sm \/ also perform the Up or Down scroll function.

Pressing [ADV] causes the system to continue executing the procedure. However, execution begins with the line that is highlighted. This feature allows the operator to advance or reverse within a procedure.

Pressing [TERM] returns control to the Test Results Display from which [LIST] was pressed; thus, it is a convenient way of continuing where the operator left off. If the operator is listing ([LIST]) a subprocedure, control returns to the main procedure by moving to the End line and pressing [ADV].

ENTERING NUMBERS

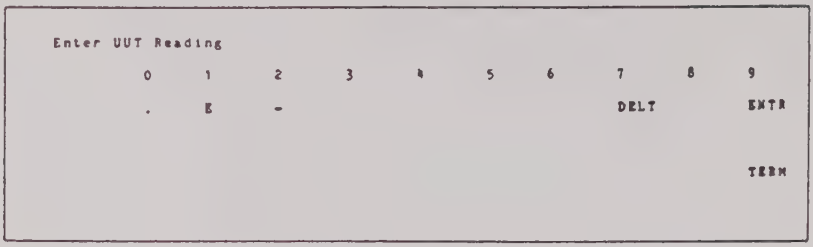


Figure 5-15. Enter Numeric Value Display

A procedure may present a display similar to the one illustrated in Figure 5-15 and instruct the operator to enter a number such as the UUT reading. This display is similar to the TSO Keyboard discussed in Section 2. Enter positive numbers by pressing the appropriate digits and the decimal point. Negative numbers are entered by first pressing the minus sign and then pressing the appropriate digits and the decimal point. Delete characters by pressing [DELT.] Press [ENTR] when the number is ready to be entered. Press [TERM] to terminate this step without entering a number.

The E character is used to indicate the exponent of the entered number. The exponent is not required for small numbers. A positive exponent represents the number of times the number is to be multiplied by 10. A negative exponent represents the number of times the number is to be divided by 10. Table 5-4 shows different ways of representing numbers using the E-format.

Table 5-4. Format Representation of Numbers

NORMAL ENTRY	E-FORMAT
100	10E1
1200	1.2E3
-127.6	-1.276E2
.0012	1.2E-3
-.00036	-3.6E-4
27000	27E3

LISTING AND SAVING RESULTS

When a procedure is finished, or if you terminate a procedure by pressing [TERM] from a Calibration Post-Test Summary, the List/Save Menu allows you to select one of the following: [LIST] or [SAVE,] [RESULTS] or [SUMMARIES] or return to the Calibration System Directory. Any selection must be confirmed by pressing the [EXECUTE SELECTION] display key. See Figure 5-16.

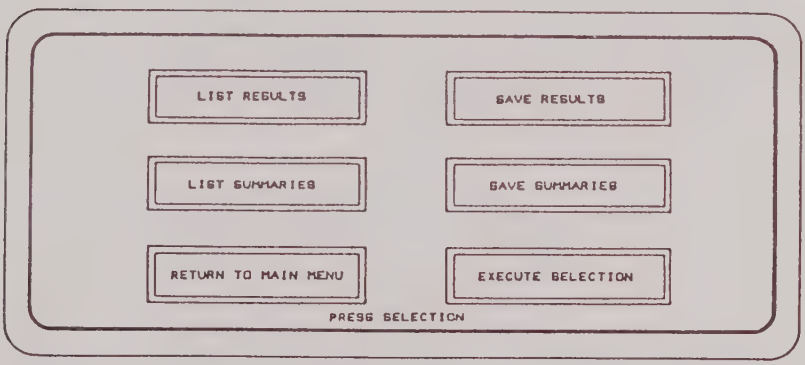


Figure 5-16. List/Save Results/Summaries Menu

If you press [LIST RESULTS] or [LIST SUMMARIES], followed by [EXECUTE SELECTION], another menu is displayed to allow you to select the list device. The List Device menu is shown in Figure 5-17.

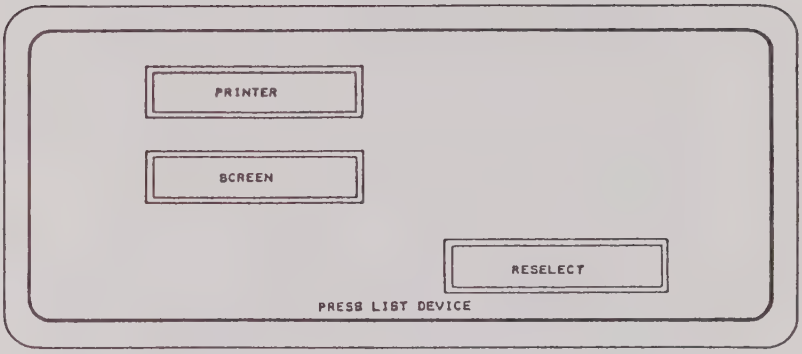


Figure 5-17. List Device Menu

Pressing [RESELECT] returns control to the List/Save Menu. Pressing [PRINTER] directs the results or summaries to an attached printer. Pressing [SCREEN] directs the results or summaries to be displayed on the screen of the 1722A Controller.

If you had pressed [SAVE RESULTS] or [SAVE SUMMARIES] in the List/Save Menu, the results would be saved on the system disk, which is a floppy disk in a Floppy Disk system or a hard disk in a Hard Disk system.

Pressing [RESELECT] in the Save Device Menu returns control to the List/Save Menu. The display key labeled [HARD DISK] will only be displayed if your 7411B system was configured as a hard disk system. You have the choice of saving the results or summaries on hard disk (only in a hard disk configured system), floppy disk (available in floppy systems) or the 1722A RS-232-C serial interface to transfer the results or summaries to a host system.

After all desired listing and saving of results and/or summaries have been accomplished, you can return control to the Calibration System Directory by pressing [RETURN TO MAIN MENU] and confirming by pressing [EXECUTE SELECTION].

NOTE:

If you do not save your results before returning to the Calibration System Directory, you will lose your results obtained during the just completed calibration procedure.

INSTRUMENT CALIBRATION ERRORS

The following paragraphs describe the type of errors reported by the System during a calibration procedure.

Error in System Executive

The system checks for errors while performing an instrument calibration. These errors may be divided into general categories. The system may detect errors while determining which instruments are present in the system. The general format of the error message is shown in Figure 5-18.

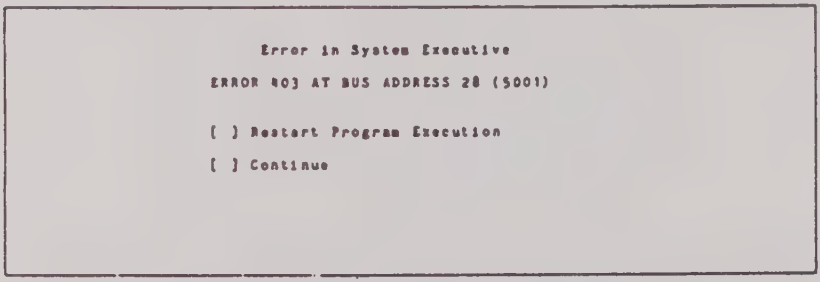


Figure 5-18. Error in System Executive Display

A System Executive error indicates a system hardware failure. The problem could be in the Controller or in another System component instrument. The error number indicates the BASIC error as described in the 1722A System Guide. The bus address indicates the suspected instrument.

Restart Program Execution will repeat the action. Continue will present the System Directory menu.

No Procedures on Disk

While selecting procedures for calibration, several errors may occur. After the requested procedure disk is inserted, the system may indicate No Procedures on Disk... for three seconds, and ask the operator to insert another procedure disk. The solution is to insert a disk that contains procedures.

Invalid Procedure

A procedure selection may be listed as an invalid procedure. This notation indicates the procedure has been destroyed or is unreadable. The operator may wish to examine a listing of the procedure by using the List, Copy, or Delete Data option.

During a calibration procedure, errors may occur. The general format of the error message is shown in Figure 5-19.

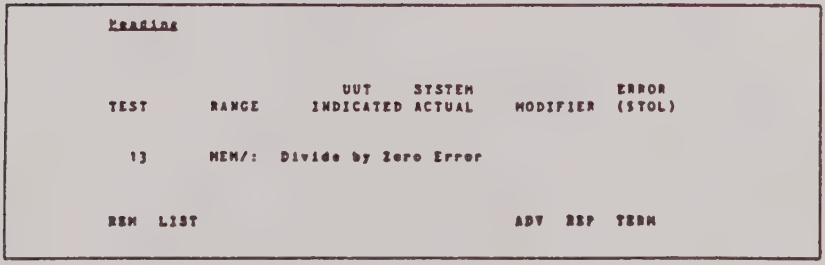


Figure 5-19. Error During Calibration Display

The TEST heading indicates the test number at which the error occurred. The FSC is the Function Selection Code for the present test. (See the Procedure Writing Manual for a description of FSCs.) The error description relates the reason for the error. Table 5-5 lists potential errors. Unless special corrective action is indicated, the operator verifies connections and repeats the test. If the error still occurs, the operator may wish to use the diagnostic tools available with some of the systems. The user also may contact a Fluke service representative with a complete description of the problem.

Not Enough Room on Disk

While saving the results on disk after a calibration, the operator may receive the message Not Enough Room on Disk.... If this occurs, none of the results will be saved on the full disk. The operator should insert another disk and repeat the save process.

Table 5-5. Instrument Calibration Error Descriptions

INSTRUMENT CALIBRATION ERROR DESCRIPTOR	EXPLANATION/CORRECTIVE ACTION
Error on Chain to 'RUN' FSC Program. (program name)	The procedure requires a BASIC program stored on the procedure disk. Ensure that the disk is mounted The operator may have to contact the procedure writer to obtain the necessary program
(undefined) FSC Not Found	The procedure contains an FSC for which there is no driver on Instrument Calibration disk. Contact the system software engineer.
Caution! Error Resetting System Hardware	The system has received an error while programming the system stimulus devices to standby. Repeat the test WARNING HAZARDOUS VOLTAGES MAY BE PRESENT AT THE INTERFACE PANEL.
MEM/: Divide by Zero Error	The system has tried to perform a divide by zero operation This error may be caused by listing to a wrong place in a procedure, or it may be a problem in the procedure itself. A repeat will not solve the problem.
FSC: BASIC Error (number) at Line (number) in (program name)	This error indicates that a non-fatal error occurred in the specified program. It could be caused by an unanticipated zero instrument response or by noise transmitted on the IEEE bus. Repeat the test.
IEEE I/O without Address Assigned	This error occurs if the procedure writer fails to specify an address during an IEEE FSC, or if the user jumps about in the procedure, hence missing the original assignment.
Error On Opening Subprocedure File (Is Proper Disk Inserted?)	This error indicates that the disk containing the subprocedure has been removed. Insert the proper disk and press ADV.

INSTRUMENT CALIBRATION ERROR DESCRIPTOR	EXPLANATION/CORRECTIVE ACTION
Subprocedures May Not Perform CALL	A subprocedure attempted to call another subprocedure. Contact the procedure writer for a solution.
Too Many CALLs in Procedure	A procedure may not include more than 32 CALL FSCs. Contact the procedure writer for a solution
CALL to Subprocedure with No Tests	The called subprocedure has no executable lines. Contact the procedure writer for a solution.
Error On CALL (Is Proper Disk Inserted?)	The disk in the drive does not contain the proper subprocedure. Verify that the proper disk is in the 1720A Controller and that the door on the drive is closed.
Error On CALL (Is Disk Inserted?)	An error has been encountered while trying to open the subprocedure. Verify that the proper disk is in the 1720A Controller and that the door on the driver is closed.
Remark File Full	The file that stores remarks and RSLTs is full and will not accept any more data. The procedure/subprocedures being executed are too long
Invalid Numeric	This error may occur while entering a number during MEMI FSC execution. Reenter the number.

Section 6
How to List, Copy, and Delete Procedures and Results

INTRODUCTION

This section explains how to list (print or display on the screen), copy, and delete procedures, results, and the Bar Code File.

OVERVIEW OF LIST, COPY, AND DELETE CAPABILITIES

The following paragraphs describe the menus and menu choices for listing, copying, and deleting different types of files to different input and output devices. Following this overview are step-by-step procedures for listing, copying, and deleting files.

File Listing Capabilities

The following file types can be listed:

- Calibration Procedure files
- Result files
- The Bar Code file
- A catalog of Calibration Procedure or Result files.

You can list from the following sources:

- Hard disk (if your 7411B system is configured as a hard disk system)
- Floppy disk (in both floppy disk and hard disk 7411B systems)

You can list a file on the screen of the 1722A controller or to a printer, provided the system has one.

File Copying Capabilities

The following file types can be copied:

- Calibration Procedure files
- Result files
- The Bar Code file

As a source device you can specify:

- Hard disk (if your 7411B system is configured as a hard disk system)
- Floppy Disk (in both floppy disk and hard disk 7411B systems)
- Remote to transfer the files from a remote system (this is available only for Calibration Procedures, Bar Code file, and Results files.

As a destination device you can specify:

- Hard disk (if your 7411B system is configured as a hard disk system)
- Floppy Disk (in both floppy disk and hard disk 7411B systems)

- Remote to transfer the files to a remote system (this is available only for Calibration Procedures, Bar Code file, and Results files.

File Deleting Capabilities

The system allows you to delete files from a source device. You can delete Results files one at a time or all at once, but you can only delete calibration procedures one at a time. The Bar Code file and calibration procedures have a safety system that requires two commands to delete them.

The current Bar Code file can be overwritten by a new Bar Code file using the [COPY] command.

HOW TO LIST, COPY, AND DELETE FILES

From the Main Menu the [LIST, COPY, OR DELETE] display key calls up the Main List, Copy, or Delete Menu, as shown in Figure 6-1. You proceed to List, Copy, or Delete a file from this menu by pressing [LIST], [COPY], or [DELETE].

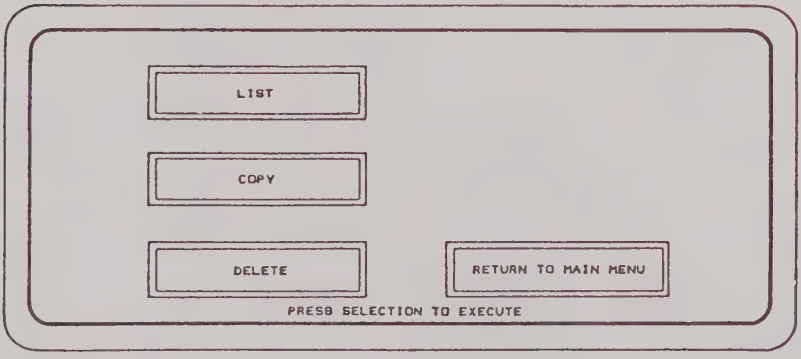


Figure 6-1. Main List, Copy, or Delete Menu

How to List Files

Pressing [LIST] on the Main List, Copy, and Delete Menu calls up the List Menu as shown in Figure 6-2. From this menu you can press [PROCEDURE] to list a procedure, [RESULTS] to list a results file, [BAR CODE] to list the Bar Code file, or [CATALOG] to list catalog of Procedures and Results.

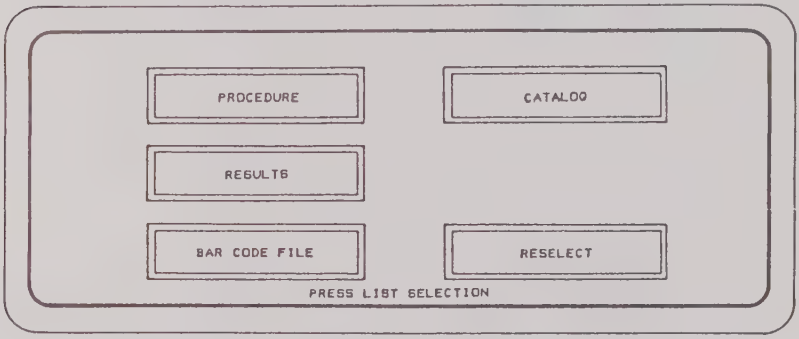


Figure 6-2. List Menu

The [RESELECT] display key returns control to the Main List, Copy, and Delete Menu.

After you select Procedures, Results, Bar Code file or Catalog, you are presented with another menu to select the source device (hard disk or floppy disk) from which to list (see Figure 6-3).

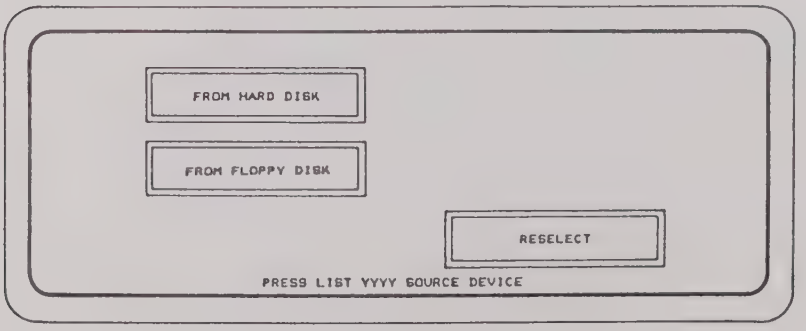


Figure 6-3. List Source Menu

In this menu the display key [FROM HARD DISK] will only be displayed if your 7411B system was configured as a hard disk based system. As in the last menu, the [RESELECT] display key returns control to the Main List, Copy, and Delete Menu.

In the List Source Menu, "YYYY" represents the type of file you selected to list (Procedure, Results, Bar Code file, or Catalog).

If you select [FROM FLOPPY DISK] you will be prompted to insert a floppy disk first before continuing to the next step.

What happens next depends on which type of file you have selected to list. Before any of the desired information is listed, you have to select the destination device, which is either the printer, if connected to the 7411B system or the screen of the 1722A controller (see Figure 6-4).

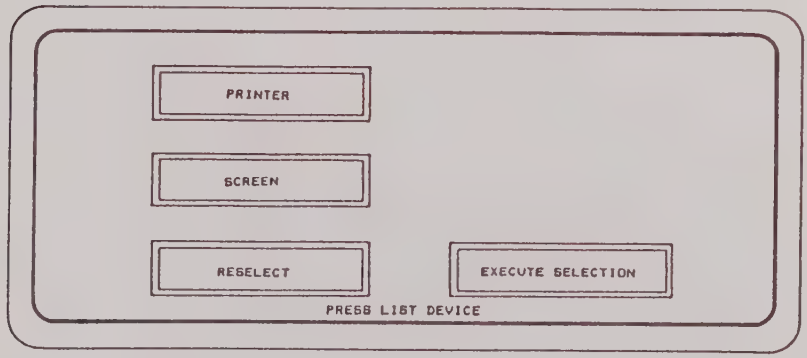


Figure 6-4. List Device Menu

If you press [RESELECT], you will return to the Main List, Copy, and Delete Menu.

LISTING PROCEDURES

If you selected in the previous menus [LIST] then [PROCEDURE], you will be presented with the Calibration Procedure Selection Menu, as shown in Figure 6-5.

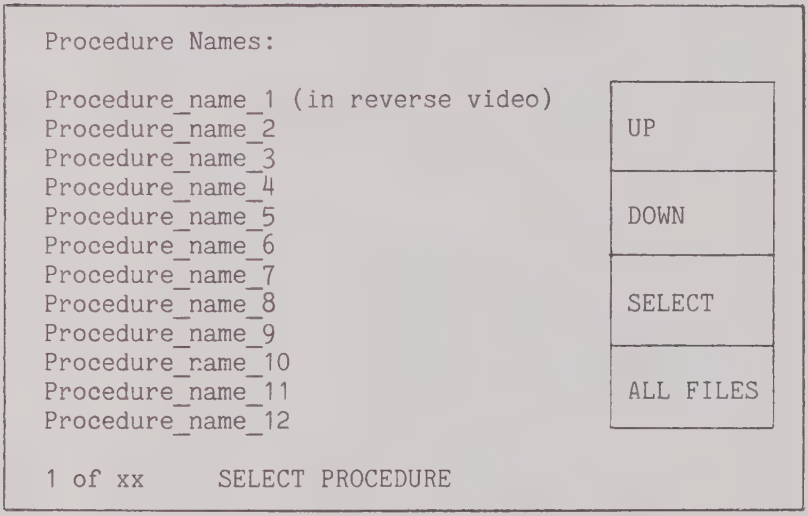


Figure 6-5. List Procedure Selection Menu

In the Procedure Selection Menu, the first procedure name is displayed in reverse video. You can move the reverse-video block up or down by pressing the [UP] or [DOWN] display key. When the desired procedure is in reverse video, you press the [SELECT] display key to list that particular procedure.

If you scroll off the screen with the [UP] or [DOWN] display key, the previous or next set of procedures will be displayed. Section 5 contains a detailed discussion on how the scrolling occurs, if you have a

question about scrolling through the menu. If you wish to display all procedure files instead of selecting a particular procedure name, you press [ALL FILES]. See Figure 6-5a for the beginning of a Procedure Listing on screen.

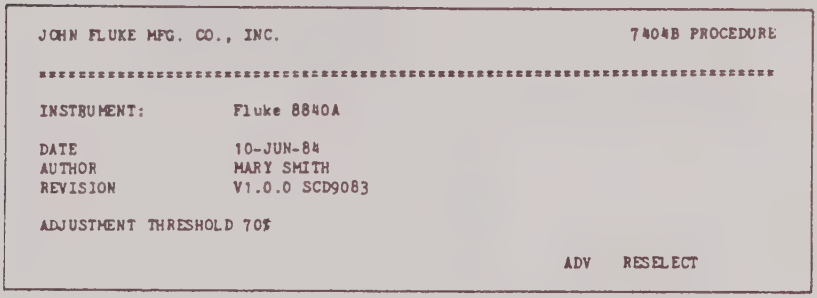


Figure 6-5a. Procedure Listed on Screen

LISTING RESULTS

NOTE:

Results on the Hard Disk are in a results directory structure. Names used consist of the UUT/Property Code, date of calibration and time of calibration and procedure used, [S (for Summary Results File), or R (for a complete Results File)], truncated so that the total file name does not exceed 51 characters. The real names, under which results files are stored, are "rslt.xx", where xx can be 1 through 99. The maximum number of result files that can be stored on disk is 99.

If you selected in the previous menus [LIST] and [RESULTS], you will be presented with the Calibration Results Selection Menu, as in Figure 6-6.

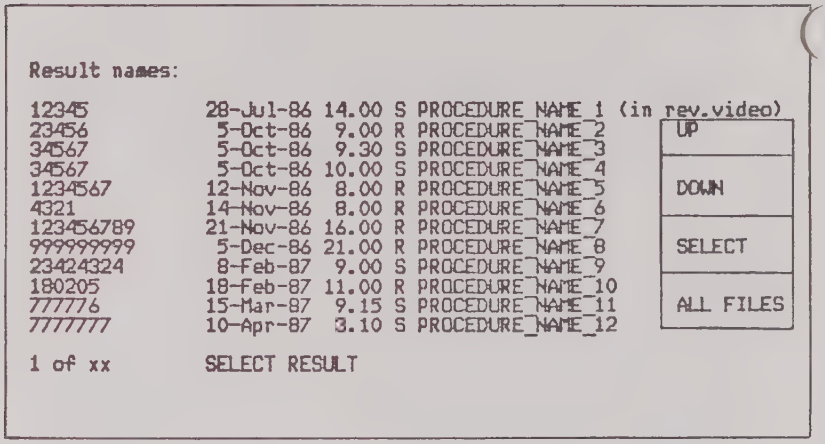

Result names:
12345 28-Jul-86 14.00 S PROCEDURE_NAME_1 (in rev.video)
23456 5-Oct-86 9.00 R PROCEDURE_NAME_2
34567 5-Oct-86 9.30 S PROCEDURE_NAME_3
34567 5-Oct-86 10.00 S PROCEDURE_NAME_4
1234567 12-Nov-86 8.00 R PROCEDURE_NAME_5
4321 14-Nov-86 8.00 R PROCEDURE_NAME_6
123456789 21-Nov-86 16.00 R PROCEDURE_NAME_7
999999999 5-Dec-86 21.00 R PROCEDURE_NAME_8
23424324 8-Feb-87 9.00 S PROCEDURE_NAME_9
180205 18-Feb-87 11.00 R PROCEDURE_NAME_10
7777776 15-Mar-87 9.15 S PROCEDURE_NAME_11
7777777 10-Apr-87 3.10 S PROCEDURE_NAME_12
1 of xx SELECT RESULT
UP
DOWN
SELECT
ALL FILES

Figure 6-6. List Results Selection Menu

As with selecting a particular result, you use the [UP] and [DOWN] display keys. If you want to see all results, you press [ALL FILES]. See Figure 6-6a for a Results Listing.

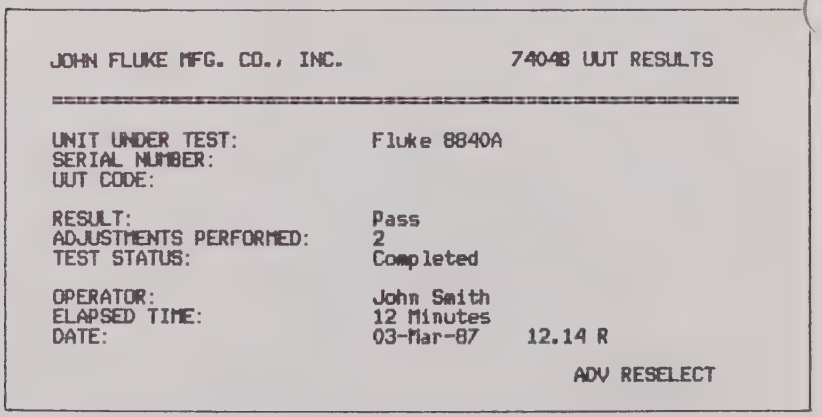


Figure 6-6a. Results Listed on Screen

LISTING THE BAR CODE FILE

There can be only one Bar Code file on any disk medium, so pressing [BAR CODE] on the List Menu followed by your selection of the source and list device (screen or printer) results in the listing of the Bar Code file.

Every line in the Bar Code file is a record. Each record consists of three fields separated by commas. The first field contains the property number, or UUT code. The second field contains the serial number of the instrument associated that property number. The third field is the name of the appropriate calibration procedure for that instrument.

LISTING THE CATALOG

It is possible to list a catalog of procedures or a list of results. After selecting [LIST] and [CATALOG], you will be prompted to choose between the two. The 7411B system will now display the headings of the procedures or results stored on the disk one by one. Figure 6-6b shows a procedure heading and Figure 6-6c shows a results heading. If the list device is a printer, all result and procedure headers are printed without interruptions.

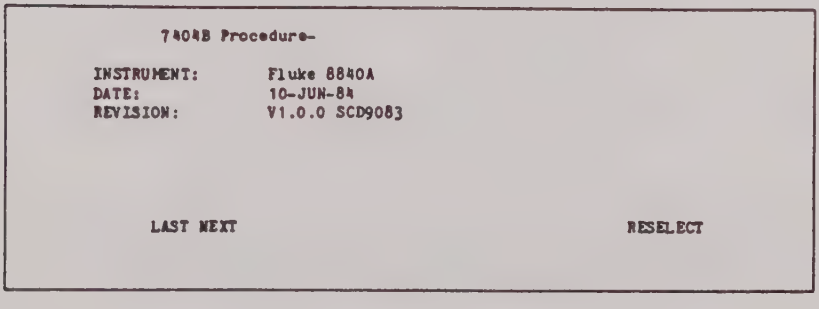


Figure 6-6b. Catalog Procedure Display

```
7404B Procedure-

UNIT UNDER TEST:    Fluke 8840A
SERIAL NUMBER:      1734181
UUT CODE:           C-2403
RESULT:             Pass
OPERATOR:           John Smith
ELAPSED TIME:       10 Minutes
DATE:               27-Jul-84  12.14 R


     LAST NEXT                                    RESELECT
```

Figure 6-6c. Catalog Results Display

How to Copy Files

Figure 6-7 shows the Main Copy Menu. You may choose to copy Procedures, Results, or the Bar Code file.

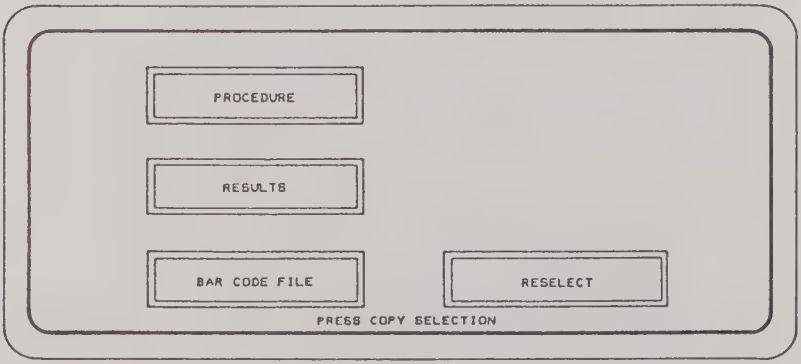


Figure 6-7. Main Copy Menu

If you press the [RESELECT] display key you will return to the Main List, Copy, or Delete menu (Figure 6-1).

After you select Procedures, Results, or Bar Code file, you are presented with another menu to select the source device (hard disk or floppy disk) from which to copy. This menu is shown in Figure 6-8.

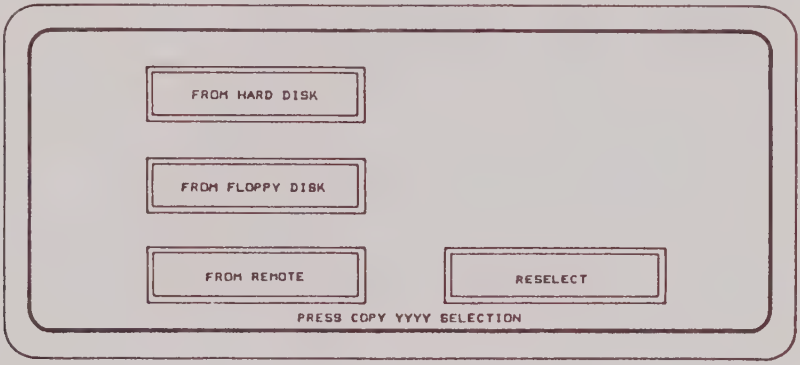


Figure 6-8. Copy Source Menu

In this menu, the display key [FROM HARD DISK] will only be displayed if your 7411B system was configured as a hard disk based system. Pressing [RESELECT] returns control to the Main List, Copy, and Delete Menu (Figure 6-1).

In this menu "YYYY" represents the type of file to be copied: Procedure, Results, or Bar Code file.

If you select [FROM FLOPPY DISK] you will be prompted to insert a floppy disk first before continuing to the next step.

What happens next depends on which type of file you have selected to copy.

COPYING PROCEDURES

If you selected in the previous menus [COPY] and [PROCEDURE], you are presented with the Procedure Selection Menu, as shown in Figure 6-9.

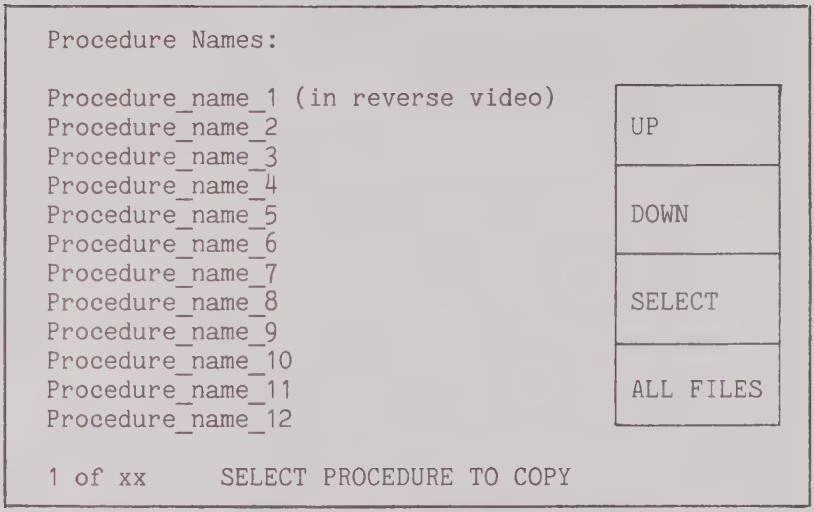


Figure 6-9. Copy Procedure Selection Menu

In this Procedure Selection Menu, the first procedure name is displayed in reverse video. You can move the reverse-video block by using the [UP] and [DOWN] display keys. When the desired procedure is in reverse video, you press the [SELECT] display key to copy that particular procedure.

If you scroll off the screen with the [UP] or [DOWN] display key, the previous or next set of procedures will be displayed. Section 5 contains a detailed discussion on how the scrolling occurs, if you have a question about scrolling through the menu. If you wish to display all procedure files instead of selecting a particular procedure name, you press [ALL FILES].

COPYING RESULTS

NOTE:

Results on the Hard Disk are in a results directory structure. Names used consist of the UUT/Property Code, date of calibration and time of calibration and procedure used [S (for Summary Results File), or R (for a complete Results File)], truncated so that the total file name does not exceed 51 characters. The real names under which results files are stored are "rslt.xx", in which xx can be 1 through 99. The maximum number of results files that can be stored on disk is 99.

If you selected in the previous menus [COPY] and [RESULTS], you will be presented with the Calibration Results Selection Menu, as in Figure 6-10.

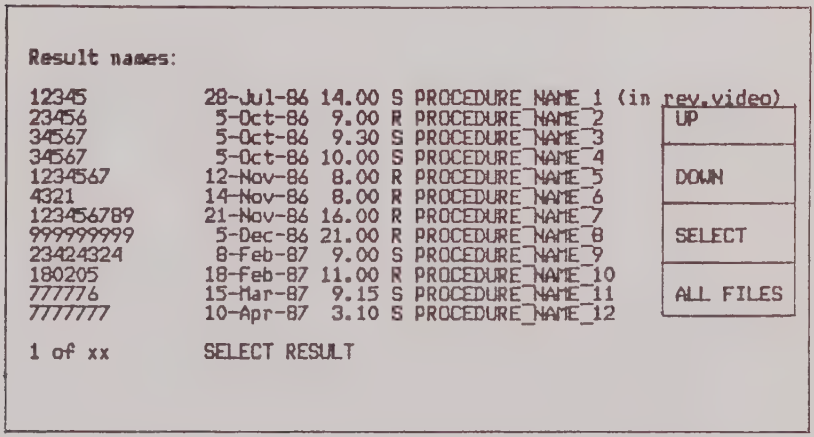


Figure 6-10. Result Selection Menu to Copy

As with selecting a Procedure, you select a particular Results file using the [UP] and [DOWN] display keys on the display. If you want to see all results, touch [ALL FILES].

The next step is to select the destination device. The Destination Device Menu is shown as Figure 6-11. If your system is not configured as a hard disk system, the display key [TO HARD DISK] is not displayed. The [REMOTE] display key lets you transfer files to or from a host computer system. The Fluke 7411A-500 software package provides an interface between industry standard database management software and the 7411B.

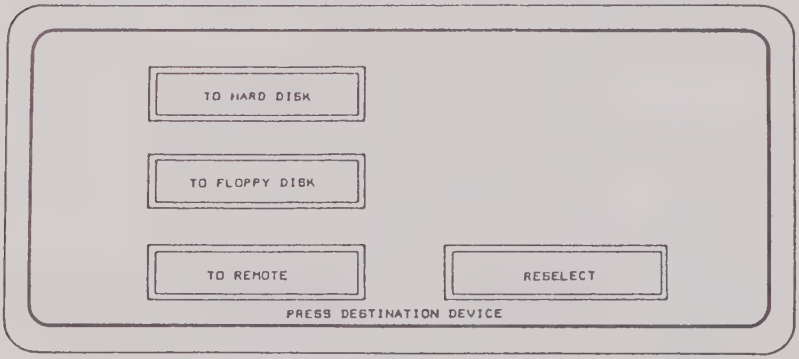


Figure 6-11. Destination Device Menu

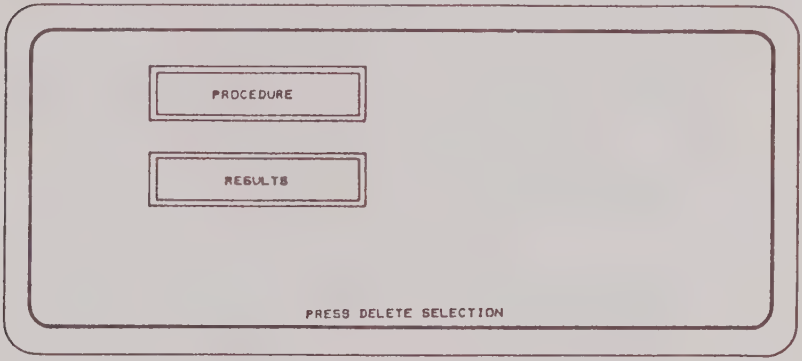
After selecting the destination to copy, copying begins. If the destination device is a disk drive, and a file with the same name exists on the disk, you are prompted to overwrite the existing file or cancel copying. After copying is complete, or after you chose not to overwrite, control returns to the Main List, Copy, and Delete Menu (Figure 6-1).

COPYING THE BAR CODE FILE

There can be only one Bar Code file on any disk medium, so pressing [BAR CODE] on the Copy Menu results in the copying of a Bar Code file to your choice of destinations.

HOW TO DELETE FILES

Figure 6-12 shows the Delete Menu. You can choose to delete Procedures or Results files. The [RESELECT] display key returns control to the Main List, Copy, and Delete Menu (Figure 6-1).



6-12. Delete Menu

After you select Procedures or Results, you are presented with another menu to select the source device (hard disk or floppy disk) from which to delete (see Figure 6-13).

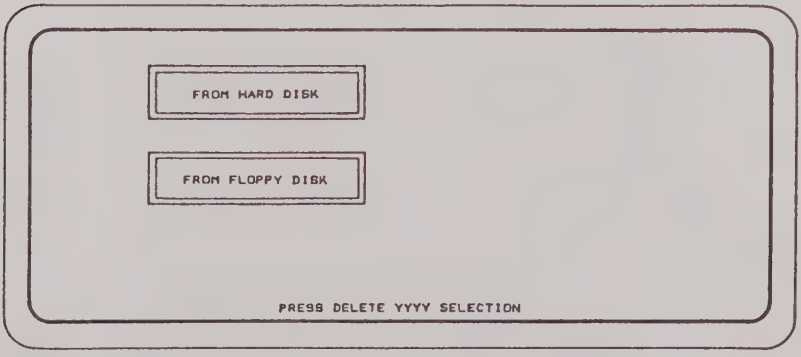


Figure 6-13. Delete Source Menu

In this menu, the display key [FROM HARD DISK] is only displayed if your 7411B system was configured as a hard disk based system. If you press [RESELECT], control returns to the Main List, Copy, and Delete menu (Figure 6-1).

In this menu "YYYY" represents the type of file to be deleted: Procedure or Results File.

If you select [FROM FLOPPY DISK], you are prompted to insert a floppy disk first before continuing to the next step. What happens next depends on which type of file you have selected to delete.

DELETING PROCEDURES

If you selected in the previous menus [DELETE] and [PROCEDURE], you are presented with the Delete Procedure Selection Menu, as shown in Figure 6-14.

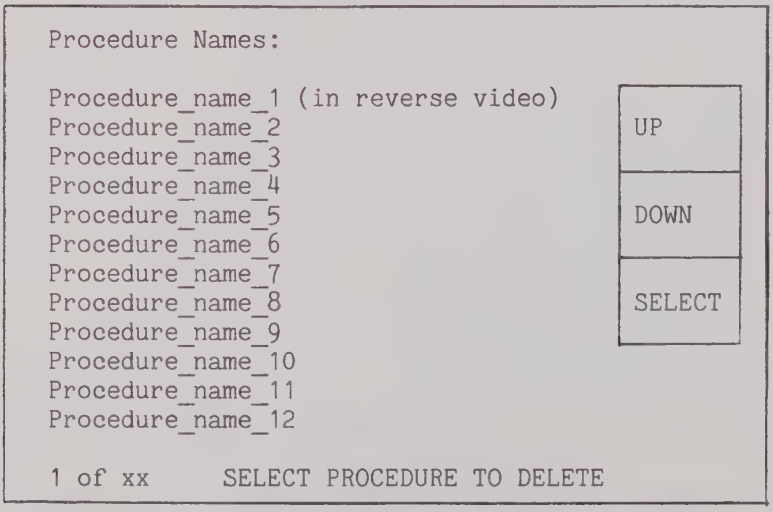


Figure 6-14. Delete Procedure Menu.

In the Delete Procedure Selection Menu, you start out with the first procedure name displayed in reverse video. You can move the reverse-video block using the [UP] and [DOWN] display keys. When the desired procedure is in reverse video, you press [SELECT] to delete that particular procedure. If you scroll off the screen with the [UP] or [DOWN] display key, the previous or next set of procedures will be displayed. Section 5 contains a detailed discussion on how the scrolling occurs, if you have a question about scrolling through the menu.

Note that you cannot delete all procedures all at once. This is prevention against accidental erasure of important files.

After you select a procedure, you are prompted to confirm that you want to delete the procedure. After you confirm by pressing [YES], deletion occurs. When deletion is completed, control returns to the Main List, Copy, and Delete Menu (Figure 6-1).

DELETING RESULTS

NOTE:

Results on the Hard Disk are in a results directory structure. Names used consist of the UUT/Property Code, date of calibration and time of calibration and procedure used [S (for Summary Results File), or R (for a complete Results File)], truncated so that the total file name does not exceed 51 characters. The real names under which results files are stored are "rslt.xx", in which xx can be 1 through 99. The maximum number of results files that can be stored on disk is 99.

If you selected in the previous menus [DELETE] and [RESULTS], you will be presented with the Calibration Results Selection Menu, as in Figure 6-15.

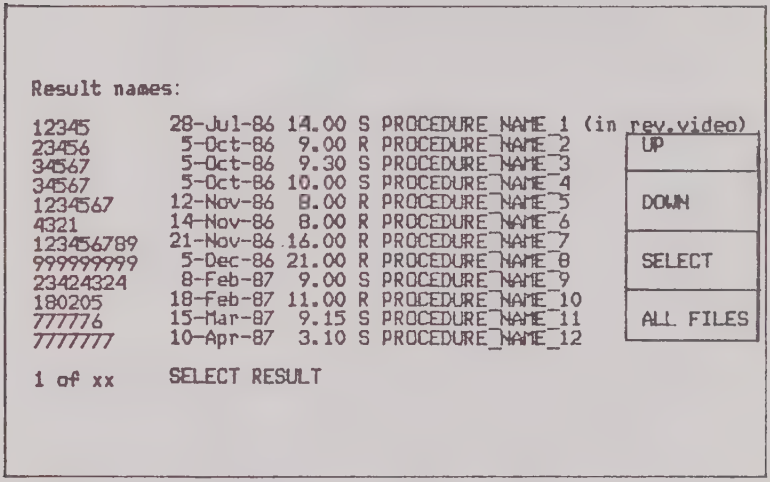


Figure 6-15. Delete Results Selection Menu

In the Delete Results Selection Menu, you start out with the first result name displayed in reverse video. You can move the reverse-video block using the [UP] and [DOWN] display keys. When the desired procedure is in reverse video, you press [SELECT] to delete that particular result. If you scroll off the screen with the [UP] or [DOWN] display key, the previous or next set of results will be displayed.

After you select a result, you are prompted to confirm that you want to delete the result. After you confirm by pressing [YES], deletion occurs. When deletion is completed, control returns to the Main List, Copy, and Delete Menu (Figure 6-1).

ERRORS

The 7411B checks for errors during List, Copy, and Delete operations and presents the List, Copy, and Delete Error Display (Figure 6-16) if an error is detected. This error display contains an error message describing the error that has been detected and [RESELECT]. Table 6-1 lists the error messages and the corrective action to take. The [RESELECT] display key allows you to return to the Main List, Copy, and Delete Menu.

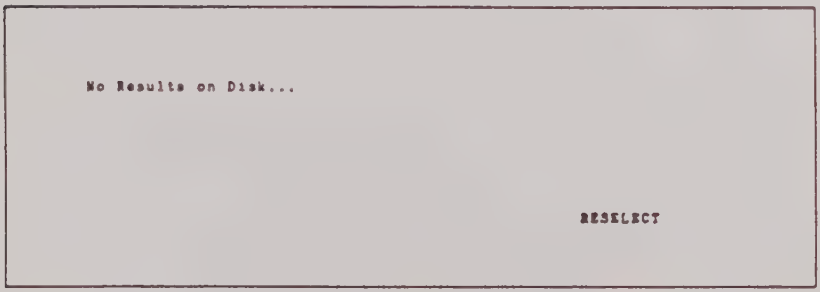


Figure 6-16. List, Copy, and Delete Error Display

Table 6-1. List, Copy, and Delete Error Messages

ERROR MESSAGE	ACTION
No Procedures on Disk No Results on Disk No Procedures or Results on Disk No Files to Delete on Disk or No Disk Inserted Not Enough Room on Disk for Copy	1. Ensure disk is properly inserted. Ensure latch over disk is securely closed. 2. Ensure proper disk is installed in drive.
Error Encountered While Opening Result File Error Encountered While Opening Procedure File Delete File Error on Disk File	1. Ensure disk is properly inserted. Ensure latch over disk drive is securely closed. 2. Ensure disk is not write protected (see 1722A Manuals) during "Copy to. . . or "Delete."
Read Error in Result File Read Error in Procedure File INVALID FILE Read Error in File Error in File Transfer to E-disk Error in File Transfer to Disk Open Error on File Open Error on Disk File	1. Ensure disk is properly inserted. Ensure latch over disk drive is securely closed. 2. Ensure disk is not write protected (see 1722A Manuals) during "Copy to. . . " or "Delete." 3. Ensure disk is formatted (FUP with /L). 4. Ensure disk blocks are good (FUP with /S).
Open ERROR on Temp File in E-disk Error on Transfer to KB2: Error on Temp File Delete	These errors indicate a potential 1722A Controller problem.

Section 7
Cal History Management

INTRODUCTION

The following information describes the use of the Cal History Management software. This information is presented in two ways. First, a tutorial of Cal History Management is presented to familiarize the user with the concepts and the execution of the software. Second, a detailed description of Cal History Management software is presented to allow full utilization of the software's options. (You should read through the tutorial before proceeding to the detailed discussion.)

The Cal History Management software is general-purpose data management software that allows the user to manipulate calibration history data to create reports. These reports are defined by the user. Typical reports might generate calibration recall lists or track instrument inventories.

Cal history management works with both 7411A and 7411B software. The calibration history management program does not use the resources of a hard disk (if one is present in the 7411B system) except for storage of the calibration history management program itself.

To protect against loss of data, you should copy calibration results onto floppy disks on a regular basis. After you do so, calibration history management operates on the information stored on the floppy disks.

The 7411B version of Cal History Management software is different from the earlier versions. It can operate now from the 1765B/10 and 1765B/20 Winchester Disks. Also, the UUT Code is matched with the Bar Code, and is no longer limited by 50 UUT Codes.

In addition, available from Fluke, is the Cal Results --> PC Software, which translates result file from the 7411B system in d Base III compatible format. The user can then use Standard dBase III programs to create the reports as desired. Refer to the Cal Results --> PC manual for more information on this additional option for managing calibration data.

PROTECTION OF CALIBRATION HISTORY INFORMATION

Any user should be concerned about the preservation of calibration data. All important data should be backed up per the requirements of your organization. The operation of the 7411B Cal History Management software emphasizes this by requiring:

- that all results be stored on Floppy Disk (even if the 7411B has been configured as a Hard Disk system)

- that the report, instrument and Cal History Data be stored on Floppy Disks.

The program can be regenerated from the Configuration Utility and Instrument Library Disks, which are delivered with the 7411B system. The user should always maintain back-up copies of procedures and the bar code file on floppy disk. During normal operation, only result files are added to the system disk(s) (floppy or hard disk).

The Cal History Management program uses only the header information from the results files; no individual result steps are used. If you wish to keep individual calibration step information, you need to preserve complete result file listings (enforced by copying results on floppy disk before using Cal History Management). Result files backed up on floppy disk can be used to append calibration summary information to the Cal History Data files.

Note that the 7411B Hard Disk system has the capacity for 99 files (although this could be extended). This enforces regular back-up to floppy disk media. By using proper care when backing up important data, the 7411B Calibration System user should have a minimal loss of data in the event of a Hard Disk crash.

CAL HISTORY MANAGEMENT TUTORIAL

The following paragraphs contain a step-by-step approach to using the Cal History Management software. This information provides the user with a thorough introduction to defining and listing reports.

Two disks, provided with the 7411B, are referenced during the tutorial. These are the 7411B Cal History Management disk and the 7411B Cal History Data disk (referred to as the Management disk and the Data disk in this section). The Management disk contains software to perform data management functions. The Data disk contains summaries of the raw calibration data obtained from the execution of a calibration procedure. The Data disk also contains sample calibration results for this tutorial. The sample results on the Data disk may be deleted if the user wishes to store new calibration results on the disk. Additional Data disks may be created using the technique described later in this section.

GETTING STARTED

Initializing the Data Disk

A new Data disk can be created from a blank formatted disk. (Refer to the 1722A System Guide for the disk Formatting procedure.) Initialization is the first step in creating a new Cal History Data disk. A newly initialized Data disk can store the calibration records (ten records each) of up to 1677 instruments.

Note

Due to the length of time required to initialize a Data disk (20 minutes!), using the procedure below, we recommend performing a "whole copy" of your Data disk, which you received with your System. Consult the 1722A System Guide for the "whole copy" of a disk procedure.

The following steps demonstrate how to initialize a blank formatted disk to create a new Data disk:

1. Select Initialize History Disk.

2. Insert the new formatted disk. Press [ADV].

3. Wait approximately 20 minutes while the disk is being initialized.

4. The new Data disk can now be used to store calibration records.

5. Press Return to System Directory.

NOTE:

Refer to Updating The Data Disk on a succeeding page for more information.

The example requires a Fluke 1722A Instrument Controller with a 512K Expansion Board. Other system hardware is not necessary.

Perform the following steps to prepare the Controller for the tutorial (in case you previously loaded Cal History Management software, select CAL HIST in the main 7411B menu):

1. Verify that the Controller is operational.

2. Insert the Management disk, and press RESTART on the front panel of the Controller.

NOTE:

You may have the Cal History Management software loaded at the same time as the 7411B software by loading the System software disk, then following the instructions on the Controller screen to load the Cal History Management software.

3. Wait approximately 1 minute while the disk loads. The Controller asks you to remove the disk and press [ADV].

DEFINING THE REPORT

Defining the contents of the report is the first step in Cal History Management. The System can store up to 32 different definitions of reports. A report definition informs the Cal History Management software of the types of data to be collected and for which instrument data will be collected.

The following steps demonstrate how a calibration report is defined:

1. From the Startup menu, select Define Report.

2. Select Modify/Create a Report. This will allow you to create a new report.

3. Select the Default Report to modify. If the cursor is not on Default Report, use [UP] and [DOWN] to position the highlight on the Default Report line.

4. Press [ADV].

5. Type SAMPLE REPORT followed by <RETURN>.

Selecting the Desired Data

The System now allows the user to select which information the report should print. Each data field has a default value. Entering [Y] for yes includes the data in the report. Entering [N] for no excludes the data from the report.

The following steps demonstrates how data is included (or excluded) from the report (entering <RETURN> selects the default value):

1. For Procedure Name enter <RETURN>.

2. For Serial Number enter <RETURN>.

3. For Location Name enter <RETURN>.

4. For Date Next Calibration enter <RETURN>.

5. For Calibration Interval enter N <RETURN>.

6. For Remarks enter <RETURN>. The remarks are general information about the instrument to be included in the history file.

7. For History Records to be printed enter <RETURN>.

8. For Operator Name enter <RETURN>.

9. For UUT Code enter N <RETURN>. The UUT Code is data entered by the operator at the time the instrument is calibrated. It might include a capital equipment code or asset number. It is typically unique for the instrument, as is the Serial Number.

10. For System Type enter N <RETURN>. (System type is the 7411B System.)

11. For Pass/Fail enter <RETURN>.

12. For Number of Adjustments enter <RETURN>.

13. For Date of Calibration enter <RETURN>.

14. For Calibration Time enter N <RETURN>.

Selecting the Desired Instruments

The System allows the user to select which instruments to include in the report. This process involves defining data that might restrict the instruments. Each field has a default value. The value [ALL] eliminates a particular field from the selection process by allowing all values of the field.

1. For Procedure Name enter <RETURN>. (All model numbers are allowed.)

2. For Serial Number enter <RETURN>. (All serial numbers are allowed.)

3. For Location Name enter PLANT 1 <RETURN>. (Only instruments from Plant 1 are included.)

4. For Date next Calibration (XX to YY) enter <RETURN>.

5. For Calibration Interval (<X, >X, or =X) enter <RETURN>. (All calibration intervals up to 255 weeks are allowed.)

6. For Remarks enter <RETURN>. (Any remarks are allowed.)

7. For Number of History Records enter 2 <RETURN>. (The last two history records will be checked for the criteria that follows.)

8. For Operator Name enter <RETURN>. (Any operator name is allowed.)

9. For UUT Code enter <RETURN>. (Any UUT Code is allowed.)

10. For System Type enter <RETURN>. (Any system type is allowed.)

11. For Pass/Fail enter <RETURN>. (Instrument results are printed whether the instrument has passed or failed.)

12. For Number of Adjustments (<X, >X, or =X) enter <RETURN>. (All Number of Adjustments are allowed.)

13. For Date of Calibration (XX to YY) enter <RETURN>. (All dates are allowed.)

14. For Calibration Time (<X, >X, or =X) enter <RETURN>. (All times in minutes are allowed.)

Listing of Information and Instruments

The System lists the information that the user chooses for the report and the instruments that are included. The following steps demonstrate how the System lists the previously defined information (report) for the selected instruments:

1. Verify that the data included in the report is correct.

2. Press [ADV].

3. Verify that only instruments from Plant 1 are included.

4. Press [ADV].

Saving the Report Definition

The report definitions are saved on the Cal History Management disk. This disk normally includes a write-protect tab in the upper right-hand corner. The tab must be removed before the report is saved.

The following steps demonstrate how to save the report definition:

1. Remove the Management disk from the Controller.

2. Remove the write-protect tab from the upper right-hand corner of the disk.

3. Replace the disk in the Controller.

4. Press [ADV]. The report definition has now been saved.

5. Remove the Management disk from the Controller.

6. Replace the write-protect tab over the slot in the upper right-hand corner of the disk.

7. Press [ADV].

8. Select Return to System Directory.

PRINTING THE REPORT

The 7411B Cal History Management software prints reports on either the Controller's screen or on an external printer.

The following steps demonstrate how to list the report on the Controller. (To list on an external printer, substitute Select Printer for Select Screen, in Step 2.):

1. Select Print Report.

2. Select Screen, then select Execute Selection.

3. Use [UP] and [DOWN] to select the SAMPLE REPORT report, then press [ADV].

4. Insert the Data disk.

5. Press [ADV].

6. Observe each page of the sample report, and press [ADV]. Only instruments from Plant 1 should be listed, and only that information defined earlier should be present.

7. When the Print Report display appears, select Return to System Directory, then select Execute Selection.

UPDATING THE DATA DISK

Updating the Data disk might involve transferring a series of calibration results to the disk, modifying or inserting new instrument data, deleting an instrument entry on the disk, or initializing a new Data disk.

Appending Results to Cal History Data Files

The Data disk must be updated with the calibration results contained on the results disk. This process might take place at the end of each work day or week. The purpose of updating the disk is to transfer calibration results to the history file associated with each instrument. If an instrument does not exist on the Cal History Data disk, the System will ask the operator if the instrument should be added to the Data File.

The following steps demonstrate how to append calibration results to the files of the Data disk:

1. Select Update History Disk.
2. Select Append Results to Files.
3. Insert a Results disk that contains valid calibration results. Press [ADV].
4. Select Update All Instruments on Disk.
5. Wait until the results are loaded into the Controller's disk, then remove the Results disk.
6. Insert the History Data disk.
7. Press [ADV].

8. If the Results disk contains results for instruments that are not listed on the History Data disk, the System stops and displays a menu. If this occurs, select Create New Instrument Entry.

9. When the Data disk has been updated with the results from the Results disk, the Update Selection Menu appears.

NOTE

After appending the Cal History Data with the results, you should archive the results and delete the results from your working medium in order to prevent full disks.

Modifying or Inserting Instruments

The listing of instruments on the Data disk may be edited to add or delete instruments. If the change involves the calibration history records, a password is required.

NOTE

The following described method is not preferred. The addition of instruments to the Instrument Data file during Appending Results to the Cal History Data files is much easier, since certain entries (Procedure Name, Serial Number, UUT Code) are copied from the header of Result files and, therefore, are guaranteed to be without typing errors.

The following procedure demonstrates how to edit the instrument listings of the Data disk:

1. From the Update Selection menu, select Modify/Insert Instrument.

2. Insert the Data disk. Press [ADV].

3. Select From Display.

4. Use [UP] and [DOWN] to select Not Defined from the list. Press [ENTR].

5. Enter the Procedure Name <RETURN>.

NOTE

The Procedure Name entry must match the entry in the INSTRUMENT field of a Calibration Procedure exactly. In the 7411B software, this entry is also the name of the Calibration Procedure file (if it is the first INSTRUMENT field).

6. Enter the Serial Number <RETURN>.

7. Enter the UUT/Property Code <RETURN>

8. Enter the Location of the instrument <RETURN>.

9. Enter a Remark for the instrument <RETURN>.

10. Enter the Calibration Interval <RETURN>.

11. Enter the Date for Next Calibration <RETURN>.

USING CAL HISTORY MANAGEMENT

The following paragraphs provide detailed descriptions of the Cal History Management software.

The Cal History Management software provides data management capabilities for instruments calibrated with the Fluke 7411B software. This software allows you to structure the data formats on the Cal History Data disk and define reports using information derived from the calibration events.

You should read the following paragraphs after reading the tutorial presented earlier in this section.

CAL HISTORY MANAGEMENT DIRECTORY

```
7411B History Management System

  [ ] Update History Disk
  [ ] Print Report
  [ ] Define Report
  [ ] Return to 7411B Main Menu
```

Figure 7-1. Cal History Management Directory

After you boot the Management disk, the Cal History Management Directory appears. Figure 7-1 illustrates the Cal History Management Directory. You may now select one of the following three history management options: Update History disk, Print Report, or Define Report.

NOTE

Most of the menus used in Cal History Management contain the Return To System Directory option. This option allows you to return directly to the Cal History Management Directory.

UPDATE HISTORY DISK OPTION

After you select the Update History disk, the System presents several options to modify the Data disk. The Data disk is the storage medium for instrument

information and calibration records. Each Data disk can hold up to 1677 instruments with 10 calibration records each. The Data disk, which contains only instrument and history information, should not be confused with the Management disk, which contains the software that performs the data management.

Append Results to Files

```
Enter Update Selection
  [ ] Append Results to Files
  [ ] Modify/Insert Instrument
  [ ] Delete Instrument
  [ ] Initialize History Disk

  [ ] Return to System Directory
```

Figure 7-2. Enter Update Selection Menu

After an instrument has been calibrated, its calibration results are stored on the Calibration Results disk (referred to as the Results disk). The Append Results to Files option allows you to append (add) these results to the Data disk. Figure 7-2 illustrates the Update Selection Menu and the Append Results To Files option. After a sufficient number of results have been saved (perhaps one day's or one week's work), they must be transferred to the Data disk.

To append (add) calibration results to the files of the Data disk, select Append Results to Files, then insert the Results disk and press [ADV]. The System loads the

new results into the E-disk of the Controller. You then insert the Data disk, and the System transfers the new calibration results to it. The System returns to the Update Selection menu when the process is complete. The tutorial (presented earlier in this section) provides a step-by-step example of this procedure.

NOTE

After appending the Results files to the Cal History data files, be certain you delete the Results files before appending them again. Cal History data files only contain information from the header of the Results files. If you wish to keep all detailed result information, you should archive these separately. Otherwise, you may find that your Hard Disk fills up quickly! In the Cal Results --> PC program, it is possible to use all results information. Again, you will find that the storage medium will be filled up quickly if you keep all the data.

UPDATE SELECTED INSTRUMENTS

After you insert the Calibration Results disk, the System asks if only selected instruments should be updated. If you select this option, the System individually lists each instrument contained on the Calibration Results disk. You may choose [ENTR] (which includes the instrument) or [NEXT] (which lists the next instrument). After you select [TERM], the System saves operator-selected results on the Data disk and returns to the Update Selection Menu. Figure 7-3 illustrates the Update Choice Menu. Figure 7-4 illustrates the Instrument Selection Display.

```
Would You Like to

   [ ] Update Selected Instruments

   [ ] Update All Instruments on Disk

   [ ] Return to System Directory
```

Figure 7-3. Update Choice Menu

```
Select Instrument to Update . . .

        Procedure Name:          Tektronix 465B
        Serial Number:           D899435
        UUT Code:                ---------
        Operator:                John Doe
        Date:                    19-Oct-81

            LAST      NEXT                    ENTR      TERM
```

Figure 7-4. Instrument Selection Display for Update

UPDATE ALL INSTRUMENTS ON DISK

If you select the Update All Instruments on Disk option, the System loads all of the results into the E-disk of the Controller. These results are then used to update the Data disk.

THE UPDATE PROCESS

After the results (either selected instruments or all instruments) are loaded into the E-disk of the Controller, the System asks the operator to insert the Data disk and press [ADV]. The System then automatically updates the Data disk. If a results file is an exact match to an existing history record for the instrument, it will not be added to the Data disk. This exclusion prevents redundancy if the same results disk is used to update on more than one occasion.

CREATE NEW INSTRUMENT ENTRY

If the Cal History Management software encounters an instrument in the results that is not on the Data disk, it lists the instrument, and the operator may select the Create New Instrument Entry option. The System creates a new entry on the Data disk for the instrument. This entry is incomplete (i.e., it does not contain Location, Remark, etc.); therefore, it will prompt you for the missing information.

INSERT ANOTHER HISTORY DISK

If the Cal History Management software encounters an instrument in the results that is not on the Data disk, it lists the instrument, and the user may select the Insert Another History disk option. The System then searches this disk for the instrument. This process may continue indefinitely.

SKIP INSTRUMENT AND CONTINUE

If the Cal History Management software encounters an instrument in the results that is not on the Data disk, it lists the instrument, and the user may select the Skip Instrument and Continue. This instrument is not added to the Data disk.

Modify/Insert Instrument

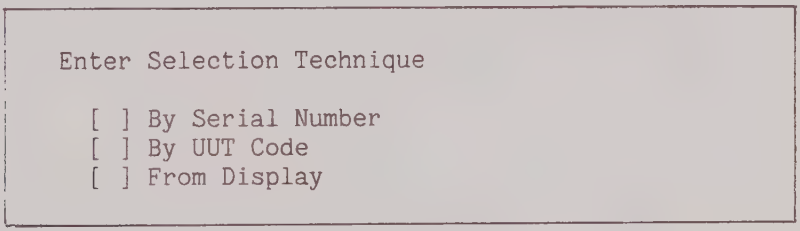


Figure 7-5. Selection Technique Menu

The Modify/Insert Instrument option allows you to edit the Cal History Data disk directly. New instruments may be added (e.g., when they are purchased), and instruments already on the Data disk may be modified. A recommended technique involves adding an instrument by appending a calibration result to the disk (this method ensures Manufacturer-Model consistency) and then modifying the entry to include calibration interval, location, etc. Both instrument data and history data may be modified.

NOTE

The System will request a password if you attempt to modify history data.

After you select Modify/Insert Instrument, the System prompts you to load the Data disk. You may then enter the selection technique and choose the instruments that are to be added or modified. Figure 7-5 illustrates the Selection Technique Menu. The tutorial (presented earlier in this section) contains a step-by-step description of this procedure.

SELECTION BY SERIAL NUMBER OR UUT CODE

The System allows you to select, by serial number or UUT Code, the instrument to be modified. If the serial number or UUT Code is not found, the System informs you and asks for the serial number or UUT Code again. If the appropriate serial number or UUT Code is found, the System asks you to verify the correct Procedure Name. If you enter [TERM], the System attempts to find another instrument with the same serial number. You may exit the by-serial-number mode of selection by entering <RETURN> with no data.

SELECTION FROM DISPLAY

```
                    SELECT INSTRUMENT

PHILIPS PM3212                  Z123456789B     P345-982
FLUKE 8840A                     *T0694*         432-3445678
TEKTRONIX 465B                                  B874059
FLUKE 8520A                     *T0625*         984-9876543
HP 3340                         ABC98765432     SN12345678-02
Not defined

          LAST  NEXT      UP    DOWN        ENTR      TERM
```

Figure 7-6. Instrument Selection Display for Update From Display

The System allows you to select an instrument to modify by choosing from a list on the Controller's Screen. Figure 7-6 illustrates the Instrument Selection Display. The [LAST] and [NEXT] display keys move the highlight from listed instrument to listed instruments. Press [ENTR] to selected the highlighted instrument. If you wish to add a new instrument to the Data disk, select the Not Defined item. Pressing [TERM] returns the System to the Update Selection Menu.

MODIFYING AN EXISTING INSTRUMENT ENTRY

You may select an instrument to modify either by serial number or from the display. The System prompts you for the type of data to modify.

Modify Instrument Data

If you choose to modify Instrument Data, the System lists the information shown in Table 7-1. This information may be modified by entering the new data followed by <RETURN>. If <RETURN> is entered with no new data, the System retains the old information. Figure 7-7 illustrates the Modify Instrument Data Display. Care should be taken to ensure that the Procedure Name is entered exactly as it appears in the procedure name for the instrument.

```
Modify Instrument Data (Input new data or <RETURN>)...

Procedure Name:                    FLUKE 1953
Serial Number:                     975-847635
UUT Code:                          ----------
Location Name:                     CAL LAB ONE
Remark:                            SYSTEM INSTRUMENT


Calibration Interval:     26
Date Next calibration:                                  22 Jun 1982
                                                        22 Oct 1982
```

Figure 7-7. Modify Instrument Data Display

Table 7-1. Entries for Modify Instrument Data

FIELD	ALLOWED ENTRIES
Procedure Name	55 alphanumeric characters. Corresponds to the INSTRUMENT field in the procedure header. Only data before a colon (:) is recognized by Cal History Management Software.
Serial Number	16 alphanumeric characters. Corresponds to the UUT serial number from instrument calibration.
UUT Code	16 alphanumeric characters. Contains the UUT Code of the instrument (UUT Code = Bar Code).
Location Name	55 alphanumeric characters. No correspondence to procedure or calibration.
Remark	55 alphanumeric characters. No correspondence to procedure or calibration.
Calibration Interval	3 integers. Corresponds to the instrument calibration cycle in weeks. 0 to 255 weeks allowed.
Date Next Calibration	2 integers, 3-character month, 4-integer year. Corresponds to the date for the next calibration of the instrument. 1 Jan 1975 to 31 Dec 2075 allowed.

Modify History Data

If you choose to modify History Data, the System asks for a password. This password assures the security of the calibration history data.

When a correct password is entered, the System allows you to select the history record you want modified. New History Record adds a new calibration result to the instrument. This option can be used to add calibration results from a manual operation. The System lists the information in Table 7-2 and allows you to enter data.

You can use [LAST] and [NEXT] to select other calibration history records. When an existing record is selected, the System lists the information shown in Table 7-2. This information may be modified by entering the new data followed by <RETURN>. If <RETURN> is entered with no new data, the System retains the old information.

Table 7-2. Entries for Modify History Data

FIELD	ALLOWED ENTRIES
Operator Name	16 alphanumeric characters. Contains the Operator Name from instrument calibration.
System Type	4 integers. Contains the name of the system on which the calibration was performed. 7401 to 7499 allowed. The word MANUAL may be entered for instruments not calibrated on a 7400-Series System.
Pass/Fail	4 characters. Contains the results of the instrument calibration. Pass or Fail allowed.
Number of Adjustments	3 integers allowed. Contains the number of calibration adjustments from the instrument calibration.
Calibration Date	2 integers, 3-character month, 4-integer year. Contains the date of the instrument calibration. 1 Jan 1975 to 31 Dec 2075 allowed.
Cal time (minutes)	5 integers allowed. Contains the time to calibrate the instrument in minutes. 0 to 65535 minutes allowed.

Neither Modify Instrument Data Nor Modify History Data

If you choose not to modify either Instrument Data or History Data, the System returns to the Update Selection Menu.

Delete Instrument

The Delete Instrument option allows you to remove an instrument from the Data disk. The System prompts you to insert the Cal History Data disk, then select the instrument (to be deleted) by serial number or from the display. When you have selected the instrument (to be deleted) the System displays Do You Really Want To Delete?... followed by the name of the selected instrument. Responding with [YES] deletes that instrument. Responding with [NO] returns the System to the Update Selection menu.

Initialize History disk

When you require a new Data disk to store results, you must either make a copy in FUP of your original Data disk, or initialize a blank formatted disk. To do this, select the Initialize History disk option. Insert the new formatted disk (refer to the 1722A System Guide for the disk formatting procedure), and press [ADV]. The System initializes the disk and returns to the Update Selection Menu. The initialization procedure is described step-by-step in the tutorial presented earlier in this section.

PRINT REPORT

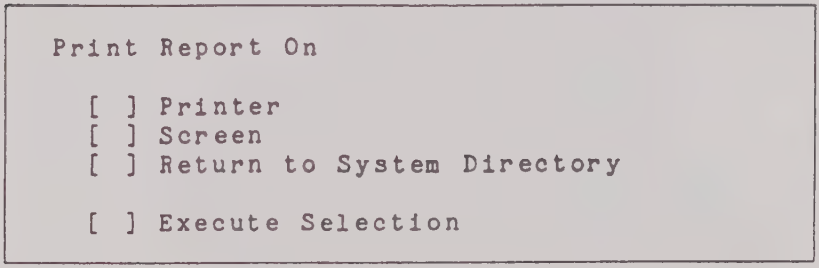


Figure 7-8. Print on Printer/Screen Menu

Cal History Management reports can be printed on the Controller's screen or on an optional printer.

To print a report, select the Print Report item from the Cal History Management Directory. The System then prompts you to select On Printer or On Screen. Figure 7-8 illustrates this menu.

Print Report on Printer

You may select to print the report on a printer. The printer must be connected to KB1 on the Controller. A report can take several minutes to print if there are numerous instruments. When the report is finished printing, the word END appears at the bottom of the report, and the System displays the Cal History Management Directory.

Print Report on Screen

The user may select to print the report on the Controller's screen. A report can take several minutes to list on the screen if there are numerous instruments. After each new page is displayed, the operator must press ADV to continue the listing. When the report is finished listing on the screen, the word END appears at the bottom of the display, and the System displays the Cal History Management Directory when the operator presses ADV.

Select Report to Print

The user selects which report to print after choosing to list on the screen or on a printer. The System displays the reports and allows the operator to select the highlighted report by pressing ADV. The user may list a new page of reports by using the LAST and NEXT keys. The user may move the highlighted line with the UP and DOWN keys. When the correct report is highlighted, the user presses ADV to print the report. TERM returns control to the Cal History Management Directory.

DEFINE REPORT

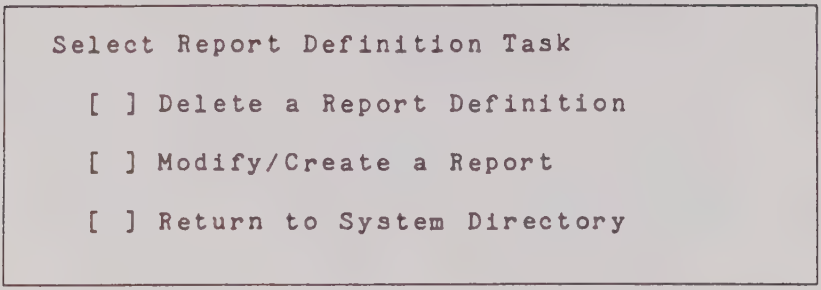


Figure 7-9. Select Report Definition Task Menu

The Define Report option allows the user to create, modify, or delete report definitions. Up to 32 reports can be stored on the Cal History Management disk. Note that the reports are not stored on the Cal History Data disk. The Select Report Definition Task Menu displays three options. Figure 7-9 illustrates the Report Definition Task Menu.

Delete a Report Definition

The System displays the reports and allows the operator to select the highlighted report by pressing ADV. The user may list a new page of reports by using the LAST and NEXT keys. The user may move the highlighted line with the UP and DOWN keys. TERM returns control to the Select Report Definition Task Menu.

When the correct report is highlighted, the user presses ADV to delete the report. The System displays, You Are About To Delete Report... followed by the name of the report. If the user presses DELT, the report is deleted. TERM returns control to the Select Report Definition Task Menu.

Modify/Create a Report

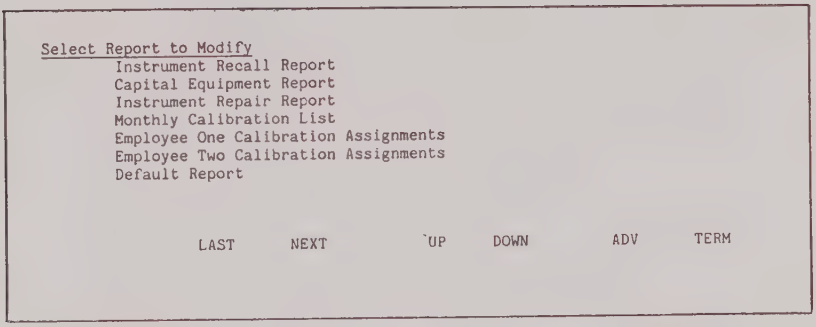


Figure 7-10. Select Report to Modify Display

The System displays the reports and allows the operator to select the highlighted report by pressing ADV. The user may list a new page of reports by using the LAST and NEXT keys. The user may move the highlighted line with the UP and DOWN keys. TERM returns control to the Cal History Management Directory. Figure 7-10 illustrates the Select Report Display.

CREATING A NEW REPORT

To create a new report, the user selects the report name Default Report. A step-by-step approach for creating a new report was described earlier in this section. The System asks the operator for the name of the report. The operator enters the name followed by <RETURN>. The System then displays the instrument information fields listed in Table 7-3. This information may be modified by entering the new data followed by <RETURN>. If <RETURN> is entered with no new data, then the System retains the old information. Y includes the listed information. N does not include the listed information. Figure 7-11 illustrates the Input Name Display. Figure 7-12 illustrates the Instrument Information Display.

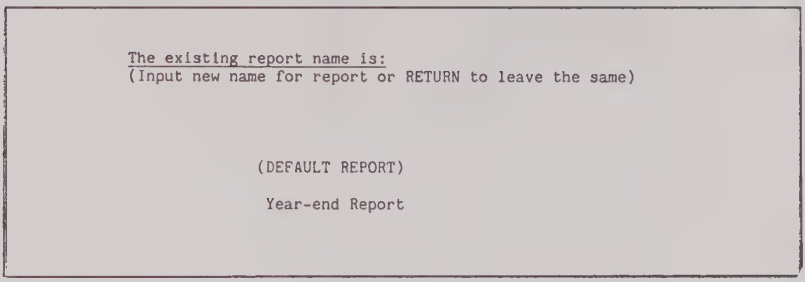


Figure 7-11. Input Report Name Display

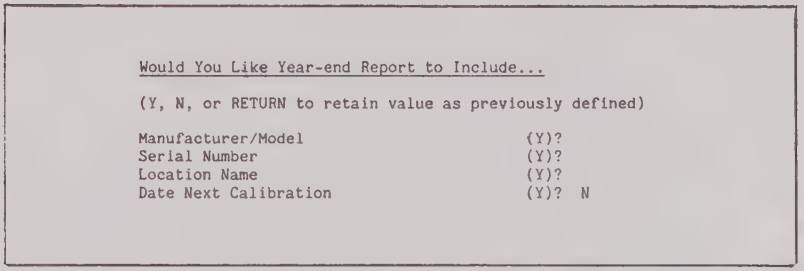

Would You Like Year-end Report to Include...
(Y, N, or RETURN to retain value as previously defined)
Manufacturer/Model (Y)?
Serial Number (Y)?
Location Name (Y)?
Date Next Calibration (Y)? N

Figure 7-12. Instrument Information Selection Display

After all of the instrument information fields listed in Table 7-3 have been entered, the System displays the instrument selection fields listed in Table 7-4. These fields select which instruments will be included in the report. The selection may be modified by entering the new data followed by <RETURN>. If <RETURN> is entered with no new data, the System retains the old information. If the instrument selection field contains the entry ALL, then this field will not be used to select instruments (all instruments are allowed). Figure 7-13 illustrates the Instrument Selection Field Display.

Table 7-3. Entries for Report Instrument Information

FIELD	ALLOWED ENTRIES
Report Name	55 alphanumeric characters. This field corresponds to the report name as it will appear in all selection displays and at the top of the report.
Procedure Name	Y: The Procedure Name of the instruments will be included in the report. Corresponds to the INSTRUMENT field in the procedure header. Only data before a colon (:) is recognized by the Cal History Management Software
	N: The Manufacturer/Model name will not be included in the report.
Serial Number	Y: The Serial Number of the instrument will be included in the report. Corresponds to UUT Serial Number from the instrument calibration.
	N: The Serial Number will not be included in the report.
Location Name	Y: The Location Name of the instrument will be included in the report. No correspondence to procedure or calibration.
	N: The Location Name of the instrument will not be included in the report.
Date Next Calibration	Y: The date for the next calibration of the instrument will be listed in the report.
	N: the date for the next calibration of the instrument will not be listed in the report.
Calibration Interval	Y: The Calibration Interval of the instrument will be included in the report
	N: The Calibration Interval of the Instrument will not be included in the report.
Remarks	Y: Any remarks about the instrument will be listed in the report. No correspondence to procedure or calibration.
	N. Any remarks about the instrument will not be listed in the report.

Table 7-3. Entries for Report Instrument Selection (cont

FIELD	ALLOWED ENTRIES
History Records	Y: Print history records. N: Do not print history records.
Operator Name	Y: Print the operator name from the calibration procedure in the report. N: Do not print the operator name from the calibration procedure in the report.
UUT Code	Y: Print the UUT Code from the calibration procedure in the report. N: Do not print the UUT Code from the calibration procedure in the report.
System Type	Y: Print the System Type on which the calibration procedure was run (74xx or manual). N: Do not print the System Type on which the calibration procedure was run
Pass/Fail	Y: Print whether the instrument passed or failed the calibration procedure. N. Do not print whether the instrument passed or failed the calibration procedure.
Number of Adjustments	Y: Include the number of adjustments that were performed on the instrument during the calibration. N. Do not include the number of adjustments that were performed on the instrument during the calibration.
Date of Calibration	Y: Include the date of the calibration of the instrument. N: Do not include the date of the calibration of the instrument.
Calibration Time	Y: Include the time it took to run the calibration procedure in minutes (from the procedure results). N: Do not include the time it took to run the calibration procedure.

Table 7-4. Entries for Report Instrument Selection

FIELD	ALLOWED ENTRIES
Procedure Name	55 alphanumeric characters. Corresponds to the INSTRUMENT field in the procedure header. Only data before a colon (:) is recognized by Cal History Management Software. ALL disqualifies the field from instrument selection (all instruments allowed). If Manufacturer/Model is chosen, only that instrument will be listed in the report.
Serial Number	16 alphanumeric characters. ALL disqualifies the field from instrument selection (all instruments allowed). If a serial number is entered, only the instrument with that serial number will be included in the report
Location Name	56 alphanumeric characters ALL disqualifies the field from instrument selection (all instruments allowed). If a Location Name is entered, only instruments from that location are included in the report.
Date Next Calibration	3 integers, TO, 3 integers. Defines the range (in days) for the next calibration date. For example, -30 to 30 would list all instruments requiring calibration from the last 30 days through the next 30 days. ALL disqualifies the field from instrument selection (all instruments allowed). Only instruments within the range are included in the report. If ALL is not selected, the report lists the results in order of date next calibration.
Calibration Interval	<(3 integers), >(3 integers), = (3 integers). Only instruments with the proper calibration interval (in weeks) are included in the report. ALL disqualifies the field from instrument selection (all instruments allowed). For example, < 20 would include only instruments whose calibration interval was less than 20 weeks.
Remarks	55 alphanumeric characters. ALL disqualifies the field from instrument selection (all instruments allowed). Only those instruments whose information includes the listed remark are included in the report.
Number of History Records	4 integers. 0 disqualifies the field from instrument selection (all instruments allowed). This field indicates the number of history records searched for selection field matches. If 0 is entered, then the system does not solicit responses for the following fields
Operator Name	16 alphanumeric characters. ALL disqualifies the field from instrument selection (all instruments allowed). Only those calibrations that include the selected Operator name are listed in the report
UUT Code	16 alphanumeric characters ALL disqualifies the field from instrument selection (all instruments allowed) Corresponds to the UUT Code field in the instrument calibration. Only instruments whose code matches are included in the report.

Table 7-4. Entries for Report Instrument Selection (cont)

FIELD	ALLOWED ENTRIES
System Type	74xx or manual. ALL disqualifies the field from instrument selection (all instruments allowed) Only those instruments calibrated on the correct system type are included in the report.
Pass/Fail	Pass or Fail. ALL disqualifies the field from instrument selection (all instruments allowed). Only those instruments that passed or failed the calibration are included in the report.
Number of Adjustments	< (3 integers), > (3 integers), = (3 integers) Only instruments with the proper number of adjustments are included in the report. ALL disqualifies the field from instrument selection (all instruments allowed). For example, < 20 would include only instruments whose calibration included less than 20 adjustments
Date of Calibration	3 integers, TO, 3 integers. ALL disqualifies the field from instrument selection (all instruments allowed). Includes only instruments calibrated within the specified time (in days) For example -100 to 0 would include only instruments calibrated in the last 100 days.
Calibration Time	< (5 integers), > (5 integers), = (5 integers). ALL disqualifies the field from instrument selection (all instruments allowed). Includes only instruments whose calibration time (in minutes) corresponds to the field. For example, < 120 includes only instruments whose calibration time was less than 2 hours.

NOTE All alphanumeric fields are case insensitive (i.e., lowercase entries are translated to uppercase entries for the purpose of instrument selection). Selection entries for alphanumeric fields search through the entire field for a match. For example, if the Manufacturer-Model field contained "Fluke," any history record containing "Fluke" in that field would be selected. Selected records might include Fluke 6011, Fluke 1953, John Fluke Mfg 1953, etc. Any spaces in this field are interpreted as part of the selection. Therefore "Fluke" is not the same as " Fluke ."

```
Which Instruments Would You Like Included In The Report...
(RETURN to use previous value, otherwise enter specific data)

Manufacturer/Model:                    ALL
Serial Number:                         ALL


Location Name

            Old:                                (ALL)
            New:                                Plant 1
```

Figure 7-13. Instrument Selection Field Display

When the instrument selection field requires a numerical entry, it requests X, XX, <X, >X, or =X. X represents an integer. Date Next Calibration is entered in days; Calibration Interval is entered in weeks; Number of Adjustments is entered in the actual number; Date of Calibration is entered in days; and Calibration Time is entered in minutes. Some information is entered as a range (e.g., Date Next Calibration). In this case the format is xx to xx. For example if the user entered -10 to 100 for Date Next Calibration, then the report would list all instruments that require calibration during the next 100 days or past 10 days.

```
Your Report Will Contain the Following Data...

Manufacturer/Model
Serial Number
Location Name
Number of History Records


                                        ADV          TERM
```

Figure 7-14. Report Information Display

After the instrument information fields and instrument selection fields are entered, the System repeats the choices. The System first lists the instrument information that will be included in the report. Figure 7-14 illustrates the Report Information Display. When the user presses ADV, the System displays the instrument selection fields. (If all fields contain ALL, no entries are listed.) Figure 7-15 illustrates the Report Selection Display. The user presses ADV to save the new report. TERM returns control to the Select Report Definition Task Menu.

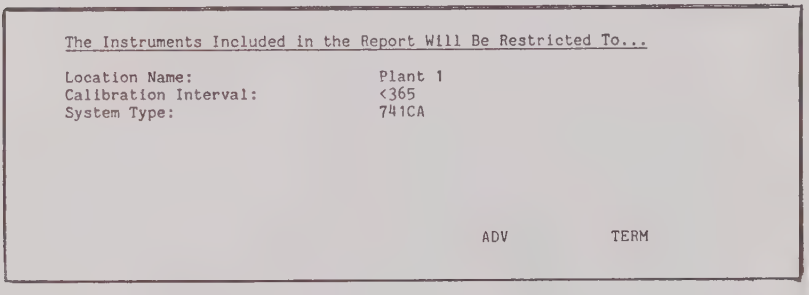


Figure 7-15. Report Selection Display

SAVING THE NEW REPORT DEFINITION

After the operator presses ADV, the System displays Remove Write Protect On disk And Insert In Drive. The user removes the adhesive tab in the upper right-hand corner of the Management disk and places the disk back into the disk drive. ADV saves the new report. TERM returns control to the Select Report Definition Task Menu. If TERM is selected, the report may be printed during the current operating session (as long as new software is not loaded); however, the report will not be saved on the Management disk.

If the Management disk is not loaded in the Controller, the System displays This Is Not The Right disk.... ADV will attempt to store the report on a new disk. TERM returns control to the Select Report Definition Task Menu.

After the report has been saved, the System displays Replace Write Protect Tab on disk.... The operator then replaces the adhesive tab on the upper right-hand corner of the Management disk. Up to 32 reports may be saved on each disk. ADV returns control to the Select Report Definition Task Menu.

MODIFYING AN EXISTING REPORT

To modify an existing report, the operator selects a report name from the Select Report to Modify Display (Figure 7-10). The System asks the operator for the name of the modified report. The new name is entered followed by <RETURN>. If <RETURN> is entered with no new name, then the old name is retained. The System displays the instrument information fields listed in Table 7-3. This information may be modified by entering the new data followed by <RETURN>. If <RETURN> is entered with no new data, then the System retains the old information. Y includes the listed information. N does not include the listed information. Figure 6B-11 illustrates the Input Name Display. Figure 6B-12 illustrates the Instrument Information Display.

After all of the instrument information fields listed in Table 7-3 have been entered, the System displays the instrument selection fields listed in Table 7-4. These fields select which instruments will be included in the report. The selection may be modified by entering the new data followed by <RETURN>. If <RETURN> is entered with no new data, the System retains the old information. If the instrument selection field contains the entry ALL, then this field will not be used to select instruments. (All instruments are allowed.) Figure 7-13 illustrates the Instrument Selection Field Display.

When the instrument selection field requires a numerical entry, it requests X, XX, <X, >X, or =X. X represents an integer. Date Next Calibration is entered in days; Calibration Interval is entered in weeks; Number of Adjustments is entered in the actual number; Date of Calibration is entered in days; and Calibration Time is entered in minutes. Some information is entered as a range (e.g., Date Next Calibration). In this case, the format is xx to xx. For example, if the user entered -10 to 100 for Date Next Calibration then the report would list all instruments that require calibration during the next 100 days or past 10 days.

After the instrument information fields and instrument selection fields are entered, the System repeats the choices. The System first lists the instrument information that will be included in the report. Figure 7-14 illustrates the Report Information Display. When the user presses ADV, the System displays the instrument selection fields. (If all fields contain ALL, no entries are listed.) Figure 7-15 illustrates the Report Selection Display. The user presses ADV to save the new report. TERM returns control to the Select Report Definition Task Menu.

SAVING THE MODIFIED REPORT DEFINITION

If no fields in the old report definition were modified, the System does not ask to save the report definition. If fields are changed, the System displays Remove Write Protect On Disk And Insert In Drive. The user removes the adhesive tab in the upper right-hand corner of the Cal History Management disk and replaces it in the disk drive. ADV saves the new report. TERM returns control to the Select Report Definition Task Menu.

If the Management disk is not loaded in the Controller, the System displays This Is Not The Right Disk.... ADV attempts to store the report on a new disk. TERM returns control to the Select Report Definition Task Menu.

After the report has been saved, the System displays Replace Write Protect Tab on Disk.... The operator then replaces the adhesive tab on the upper right-hand corner of the Management disk. Up to 32 reports may be saved on each disk. ADV returns control to the Select Report Definition Task Menu. The Management disk now contains the modified report listed under the new name.

FIELD NAMES, SIZE, AND FUNCTION

The Cal History Management software contains default values of field size, number of allowable field entries, and field function. Some of these parameters may be modified. Table 7-5 lists the number of unique entries and maximum field length for each of the fields that contain restrictions.

FIELD	MAXIMUM NUMBER OF UNIQUE ENTRIES	MAXIMUM LENGTH
Manufacturer/Model	300	56
Location	50	56
Remark	25	56
Operator Name	20	16

Table 7-5. Limits for Restricted Fields

SYSTEM PASSWORD

The Cal History Management software allows the user to define a System password. This password is required whenever an operator desires to modify history data on an instrument calibration.

Defining the Password

The password is defined when the software is loaded into the Controller. If no password has been previously entered, then the following sequence takes place:

1. The System asks, Do you desire to enter a System password?

2. If the user answers NO, the System displays the Cal History Management Directory. (In this case the System will prompt for a password the next time the software is loaded.)

3. If the user answers YES, the System enables the keyboard and allows a password up to 32 characters.

4. The System displays the password and asks, Do you desire the password to be XXXX? If the user answers NO, step 3 is repeated. If the user answers YES, the password is recorded.

5. The password is case sensitive (i.e., password is not the same as PASSWORD).

6. If just <RETURN> is entered for the password, then the System does not require a password to modify calibration history data.

Using the Password

The System automatically prompts the operator for the password whenever an attempt is made to modify calibration history data (unless just <RETURN> is entered for the password). When the operator types the password, the entry does not appear on the Controller's screen.

1722A controller disks, 2-6
7411B documentation, 1-3
7411B system software system directory, 4-2
Append results to files, 7-15
adjusting the UUT, 5-18
adjusting the stimulus or display, 5-11
adjusting the system stimulus, 3-7
alphanumeric keyboard screen, 2-11
backup and archive disks, 2-6
blank procedure disk, 2-4
Cal history management directory, 7-14
Cal history management tutorial, 7-3
Cal history management, 7-1
cal history data disk, 2-5
cal history management (optional), 4-3
cal history management disk, 2-5
calibrate an instrument, 4-2
calibration adjustment, 3-9
calibration results disk, 2-5
calibration software disk, 2-4
calibration test results, 5-14
calibration, 5-1
configuration manual, 1-3
continuing with dc voltage calibration, 3-10
copy files, 6-10
dc voltage calibration, 3-7
define report, 7-28
defining the report, 7-6
delete a report definition, 7-28
delete files, 6-15
delete instrument, 7-2
display keys, 2-10

enter new operator name, 4-3
entering numbers, 5-24
entering uut serial number and code, 3-6
erors, 6-19
field names, size and function, 7-39
file copying capabilities, 6-2
file deleting capabilities, 6-3
file listing capabilities, 6-1
formatting a new procedure and results disks, 4-5
graphic locator, 5-8
initialize history disk, 7-26
initializing the system, 2-15
instrument calibration errors, 5-28
introductory training manual, 1-4
list files, 6-4
list, copy, or delete, 4-2
listing and saving results, 5-25
listing the procedure, 5-22
loading the procedure, 5-3
making connections, 2-14
making connections, 5-8
manual usage and personnel, 1-5
menus, 2-8
modify/create a report, 7-29
modify/insert instrument, 7-19
organization, 1-2
post-test summary, 3-8
preliminary operation, 3-6
print report, 7-26
printing the report, 7-10
procedure selection, 5-3
procedure termination and results options, 3-11
procedure writing manual, 1-3
protection of calibration history information, 7-2
resetting the date-time clock, 2-22
returning to the system directory, 3-15
saving procedure results on a disk, 3-13
software description, 2-1
system disks, 2-4
system features, 2-7
system password, 7-39
test failure and calibration adjustment, 3-9

the operator's aid, 2-12
touch sensitive overlay (TSO) display, 2-7
training, 1-7
update history disk option, 7-14
updating the data disk, 7-11
using Cal history management, 7-13
uut results listing, 3-12
write or modify a procedure, 4-4

7411B
CALIBRATION SOFTWARE

Configuration Manual

P/N 797050
MARCH 1987
©1987, John Fluke Mfg. Co., Inc.
All rights reserved. Litho in U.S.A.

FLUKE®

CONTENTS

SECTION	TITLE	PAGE
1	INTRODUCTION, SPECIFICATION, AND SAFETY	
	INTRODUCTION	1-1
	The 7411B Manual Set	1-1
	7411B Operator Manual	1-1
	7411B Introductory Training Manual	1-2
	7411B Procedure Writing Manual	1-2
	Arrangement of the Configuration Guide	1-2
	SPECIFICATIONS	1-4
	SAFETY INFORMATION	1-5
	DIFFERENCES BETWEEN 7411A AND 7411B SOFTWARE	1-6
	DIRECTORY STRUCTURES	1-6
	BAR CODE CAPABILITY	1-8
	SELECTION OF PROCEDURES	1-9
	CONFIGURATION	1-9
2	DEFINITIONS AND APPLICATIONS	
	COMPUTER-AIDED CALIBRATION	2-1
	Automated Calibration System	2-2
	Calibration Clusters	2-2
	Automated Calibration Workstations	2-2

3 INSTALLATION AND APPLICATION NOTES

INTRODUCTION 3-1
Calibration Clusters 3-1
Calibration Workstations 3-1
Calibration Systems with Winchester Disk Option 3-2
Calibration Systems with Bar Code Reader 3-2
Information Provided for Winchester Disk Option 3-2
Information Provided for Installing a Bar Code Reader 3-2
Information Provided for Calibration Clusters 3-2
Information Provided for Calibration Workstations 3-2
FUNCTIONAL INTEGRATION TESTS (FIT) 3-3
PERFORMANCE VERIFICATION (PV or WPV) 3-3

INSTALLING A 7404A 3-5
INTRODUCTION 3-5
7404A SYSTEM DESCRIPTION 3-5
APPLICATION NOTES 3-8
UNPACKING AND INSTALLING THE 7404A 3-8
Unpacking the 7404A 3-9
Installing the System 3-9

INSTALLING A 7404B 3-13
INTRODUCTION 3-13
7404B SYSTEM DESCRIPTION 3-13
APPLICATION NOTES 3-16
UNPACKING AND INSTALLING THE 7404B 3-16
Unpacking the 7404B 3-17
Installing the 7404B 3-18

3 INSTALLATION AND APPLICATION NOTES (cont)

INSTALLING A 7409A 3-23
INTRODUCTION 3-23
7409A SYSTEM DESCRIPTION 3-23
APPLICATION NOTES 3-25
UNPACKING AND INSTALLING THE 7409A 3-26
Unpacking the 7409A 3-26
Installing the 7409A 3-27

INSTALLING A 7449A 3-31
INTRODUCTION 3-31
7449A SYSTEM DESCRIPTION 3-31
APPLICATION NOTES 3-34
UNPACKING AND INSTALLING THE 7449A 3-35
Unpacking the 7449A 3-35
Installing the 7449A 3-36

INSTALLING A USER-DEFINED SYSTEM 3-41
INTRODUCTION 3-41
UDS DESCRIPTION 3-41
Overview 3-41
Computation and Control 3-45
DC and Low-Frequency Stimulus 3-46
Pulse and Waveform Stimulus 3-46
RF Stimulus 3-46
Measurement 3-46
Application Notes 3-47
INSTALLING A UDS 3-47

WORKSTATION INSTALLATION 3-51
TYPES OF WORKSTATIONS 3-51
DEFINITIONS 3-51
INSTALLING STANDARD WORKSTATIONS 3-52
7405A 3-52
7410A 3-52
A123-CO-nn and A123-PE-nn 3-53

3 INSTALLATION AND APPLICATION NOTES (cont)

INSTALLING CUSTOM WORKSTATIONS 3-53
Combined 7405A/7410A 3-53
Application Information 3-53
ALL OTHER WORKSTATIONS 3-54
Application Information 3-54
USER-CONFIGURED ARRANGEMENTS 3-54

4 CONFIGURING YOUR 7411B

INTRODUCTION 4-1
DECISION FACTORS 4-5
CHOOSING A SYSTEM FOR YOUR WORKLOAD 4-6
New Installations 4-6
Upgrading Existing Systems 4-9
CHOOSING THE SOFTWARE FOR YOUR SYSTEM 4-9
PGE and INT Operating Code 4-9
Calibration History Management Software 4-10
5200A-800 Software 4-10
7411B PROCEDURES 4-10
General Information 4-10
Fluke Example Procedures 4-11
User's Group Procedures 4-12
FIT and WPV 4-12
OPERATING CODE 4-14
Overview 4-14
Step-by-Step Description 4-15
TRANSLATING A PROCEDURE 4-51
Introduction 4-51
Translation of 7411A Disks to 7411B Disk 4-52
Copying BASIC Routines 4-55
Translating a Procedure from
Pre-7411A to 7411A 4-57

4 CONFIGURING YOUR 7411B (cont)

EDITING A PROCEDURE TO RUN ON YOUR SYSTEM 4-67
Why a Translated Procedure May Need Editing 4-67
Editing for Different Instruments 4-68
RUNE 4-68
ADDING A PRINTER OR BAR CODE READER
TO YOUR SYSTEM 4-69
PORT CONNECTIONS OF PRINTER AND
BAR CODE READER TO THE 1722A 4-69
Serial Port Characteristics 4-69
Printer Information 4-70
BAR CODE READER INFORMATION 4-71
Bar Code Reader Equipment 4-71
Connecting the Bar Code Reader to the 1722A 4-73
Setting up the INTERMEC 9510 Bar Code Reader ... 4-73
An Explanation of the STRTUP.CMD File 4-74
An Explanation of the "COMMND.INT" File 4-76
Modifying STRTUP.CMD & COMMND.INT
Files for Serial Ports 4-77
INITIALIZING A HARD DISK FOR YOUR
7411B SYSTEM 4-81
Introduction 4-81
Initialization 4-81

APPENDIX DATA SHEETS

Section 1
Introduction, Specifications, and Safety

INTRODUCTION

The 7411B Manual Set

The 7411B Calibration Software is primarily supported by four major manuals in two volumes (binders). Volume 1 contains the Introductory Training Manual and the Procedure Writing Manual. Volume 2 contains the Operator Manual and Configuration Manual. In addition, Volume 2 contains two supplementary manuals: the 5200A-800 Manual and System Builder's Guide, both of which are used for reference purposes. Volume 1 also contains a supplementary manual, How To Use These Manuals.

This is the Configuration Manual. The following paragraphs briefly describe the other major manuals in the 7411B Manual Set. Refer to Volume 1, How to Use These Manuals, for more information.

7411B Operator Manual

The 7411B Operator Manual describes how to operate the 7411B Calibration Software (referred to in this manual as the 7411B). It includes examples and a step-by-step tutorial describing how to use the 7411B to calibrate an instrument and handle data. This manual is intended for individuals who will operate the system.

7411B Introductory Training Manual

If you have little or no background in procedure writing, the 7411B Introductory Training Manual is a good place to improve you skills. In the 7411B Introductory Training Manual you will find FSC descriptions, exercises dealing with FSCs, and answers to the exercises. Use the 7411B Introductory Training Manual, in conjunction with the 7411B Procedure Writing Manual, to develop or enhance your procedure-writing skills.

7411B Procedure Writing Manual

The 7411B Procedure Writing Manual explains how to write or modify calibration procedures. The manual is intended for technicians or engineers who have a working knowledge of instrument calibration. However, writing and modifying procedures does not require programming experience.

Arrangement of the Configuration Guide

This Configuration Guide is arranged into four sections that can be used to help a system manager configure the 7411B operating software for a specific Computer-Aided Calibration system. This is section 1 of the Configuration Guide. Section 2 summarizes the definitions of "system", "calibration cluster" and "workstation" and identifies the key calibration applications of the 7411B. Section 3 discusses the hardware configuration, installation and application of nine different 7411B based systems. Section 3 is complementary to section 4.

Section 4 is the heart of this guide. It gives the step by step procedures for:

- Configuring the Operating Code for your system.
- Translating procedures that were written for the 7411A or pre-7411A systems into procedures that will run on the 7411B controlled systems.
- Translating files created by 7411A systems in a format compatible with 7411B.
- Editing these procedures to compensate for any differences in instrumentation that may exist between the original system and yours.
- Adding a printer that you supply for your system.
- Adding a bar code reader that you supply for your system

IMPORTANT SOURCE CODE INFORMATION

THE 7411A'S CONTROL DATA ARRAY IS DIFFERENT THAN THE CONTROL DATA ARRAY FOR THE PRE-7411A SOFTWARE SUPPLIED WITH THE 7405A, 7410A, 7404B AND A123 SYSTEMS. IF YOU HAVE MODIFIED THE SOURCE CODE OF THE SOFTWARE THAT WAS SUPPLIED WITH THESE OLDER MODELS OR IF YOU HAVE WRITTEN BASIC PROGRAMS THAT MAKE USE OF THE CONTROL DATA ARRAYS FOR THESE SYSTEMS (EXCEPT AS DEFINED HEREIN FOR THE RUNE FUNCTION SELECTION CODE) YOU MUST OBTAIN 7411B SOURCE CODE AND MODIFY IT AND THE BASIC PROGRAMS THAT USE THE CONTROL DATA ARRAYS TO MAKE YOUR PROCEDURES THAT USE YOUR PREVIOUSLY MODIFIED SOURCE CODE COMPATIBLE WITH THE 7411B.

IMPORTANT SOURCE CODE INFORMATION, CONT.

THE CONTROL DATA ARRAY OF THE 7411B AS FAR AS RELATING TO BASIC PROGRAMS IS IDENTICAL TO THE CONTROL DATA ARRAY OF THE 7411A. THE ONLY DIFFERENCE BETWEEN THE 7411A AND 7411B IS THAT IN THE 7411B A DIRECTORY STRUCTURE IS NEEDED TO ACCESS FILES. THE TRANSLATION UTILITY CREATES THIS DIRECTORY AND DOES NOT MAKE ANY CHANGES TO THE PROCEDURE FILES.

SPECIFICATIONS

Diskette Environment

Operating:	10°C to 51.6°C, 8% to 80% R.H.*
Storage:	10°C to 51.6°C, 8% to 80% R.H.*
Shipping:	-40°C to 51.6°C, 8% to 80% R.H.*

* non-condensing

1722A E-Disk Memory

Available:	1092 Blocks with one 512K-Byte RAM Expansion option installed.
	2116 Blocks with two 512K-Byte RAM Expansion options installed.
Typical Usage:	< 1092 Blocks for a combined PGE/INT with 5 or 6 instruments co-resident in E-Disk.
Maximum Usage:	1498 Blocks for a combined PGE and INT with all instruments plus Cal History Management co-resident in E-Disk.

SAFETY INFORMATION

The 7411B provides an orderly routine for setting the system stimulus instruments to standby when it receives an interrupt from the Operators Aid or the 1722A's keyboard, softkey pad and its ABORT or RESTART keys. This capability is not automatically carried over into BASIC programs that the user writes. The user who writes BASIC programs should put 'on-key go to' routines in his or her programs to handle these interrupts. See the 1722A BASIC Manual Index under the 'ON event' entry for cross-referenced information on interrupt handlers.

The 7411B is designed to allow its users to obtain local (front panel) access to the controls of the instruments in it. In addition, some instruments do not implement the local lockout capability of the IEEE-488 protocols. A user may inadvertently leave an instrument in the local state. When this is the case, that instrument may not be set to standby during the processing of an interrupt by the 1722A.

Consult the IEEE-488 interface section of the instruction manual for each instrument to determine how it behaves when it receives a device clear and whether or not it implements local lockout.

It should also be noted that there may be failure modes for the IEEE-488 bus itself or in the devices that it communicates with that will preclude an instrument from responding to an IEEE-bus transmitted command to be set to the standby state.

A system operator should always be cautious when connecting or disconnecting the analog signal test leads between a UUT and the system stimulus or measurement instrumentation or Test Interface Panel (TIP). This is especially true when there is an indication of an abnormal system condition or when the operator has manually operated one or more of the system instruments.

DIFFERENCES BETWEEN 7411A AND 7411B SOFTWARE

Users familiar with the Fluke 7411A Calibration system will find that the core capability of the 7411A system has not changed. The methods by which calibration procedures are defined and how these procedures are actually executed has not changed. Procedures developed for the 7411A can be run on a 7411B system, albeit that the disk formatting is different. A program is provided with the 7411B system that reformats a 7411A procedure disk in a 7411B procedure disk. (The method of translating 7411A procedures into 7411B format is described in Section 4 of this manual.)

There are significant differences how the various programs in the 7411B system are invoked and how utilities (e.g. list, copy and delete) are used. These differences are mainly caused by:

1. The addition of a Winchester Disk as a mass storage medium.

2. The ability to read bar codes and initiate execution of a calibration procedure directly by bar code reading.

There are other, small improvements to the 7411B software.

DIRECTORY STRUCTURES

The 7411A system names the procedures in sequence (PROCED.1, PROCED.2, etc.). A procedure is accessed by stepping through the procedures one by one. First the header of procedure #1 is displayed and the operator decides to choose that one or proceed to the next. The number of procedures that can be stored on a floppy disk is limited, typically about 25 per floppy disk.

If was obvious that if a mass storage device was to be used to store many more times the number of procedures normally found on a floppy disk, sequentially accessing calibration procedures would be inefficient. Files in the 7411B system therefore are accessed differently: they are accessed directly by specifying an appropriate file name. This makes displaying each headers to the operator for his decision unnecessary.

File names in the 1722A controller cannot be longer than six characters plus a possible extension of three characters. The goal in the 7411B was to provide descriptive file names to minimize the difficulty of selecting a procedure from a listing. It was decided that six characters were not sufficient for this purpose. Therefore it was decided that the mass storage media would have directory structures, which more-or-less function as a telephone directory: when a file is needed from a mass storage medium, its (long) name is looked up in the directory; the long file name is associated with the actual (six characters) short name (corresponding to the telephone number in a telephone directory) and the actual file is accessed. A maximum of 1023 procedures can be stored on a disk.

It was furthermore decided that for procedures the name to the used for the file would be identical to the entry in the first INSTRUMENT: field in the procedure header. The maximum number of characters in that field is 51, and therefore the file names in the 7411B system can be that long.

The 7411B system always tries to store procedure files named as shown in their first instrument field. Renaming a procedure is therefore only accomplished by changing that instrument field entry in the procedure itself.

Directory structures are also used for accessing result files quickly. The virtual name for the result file consists of: UUT/Property Code, an R (for complete Result file) or an S (for Summary Result file), the date of calibration, the time of calibration, the and name of the procedure (truncated so that the length of the virtual file name is limited to 51 characters).

The actual file names used are "rslt.xx", where xx is 1 through 99. A maximum of 99 result files can be stored on the disk.

BAR CODE CAPABILITY

The 7411B system provides means to read bar codes and start up the appropriate calibration procedure from information stored in a "bar code" file. The bar code file is an ASCII file, which contains for every occurrence of a bar code:

- The bar code or property code itself.
- The serial number of the instrument to be calibrated.
- The name of the calibration procedure to be used.

The user can add and delete property codes and additional information from the bar code file. The search time for the bar code increases linearly with the number of barcodes. For 5000 barcodes, the search time can be up to 30 seconds. When a calibration procedure is started up with the bar code reader, the operator does not have to enter serial number and the UUT or bar code; this information is automatically entered from the bar code file under that particular property code.

SELECTION OF PROCEDURES

Calibration procedures can be selected in the 7411B much faster than in the 7411A system. When in the 7411B Main System Directory "CALIBRATE UUT" is selected, the 1722A touch sensitive screen displays the first 12 possible selections. The first selection is manual entry of property number. It shows up in reverse video. This option can be used to enter a property code even if a bar code reader is not available. The next 11 lines contain names of the first 11 procedures on the storage device. Display keys on the screen allow the user to scroll the reverse-video block to the next line up or down. If the reverse-video block reached the top or bottom of the screen, the next set of 12 procedures is be displayed.

When the reverse-video block is over the name of the desired procedure, the user presses SELECT to start up this procedure.

The bar code reader can be used to select a procedure instead. If it is used, the procedure name and additional information is looked up in the bar code file and the procedure starts up without the prompts for UUT or property code and serial number.

CONFIGURATION

The 7411B package supports the 1765B Winchester disk medium as well as the traditional 7411A-style floppy disk based system. The removable disk is not supported. During configuration of the 7411B system it is possible to define the system as "Hard Disk" or "Floppy Disk" based. While executing procedures or editing procedures, the 7411B system, with few exceptions, expects the appropriate files to be present on the "system drive".

In the List, Copy and Delete Menus, selections are available to copy files from one type of media to another. This feature is useful, because in order to use a procedure on a floppy disk in a hard disk based system, the procedure must first be copied from the floppy on the winchester disk.

During configuration it is possible to define headers for procedure and result files and a replacement for "UUT CODE" in the procedure header. Those can be customized at the time of configuration. Previously, source code in the interpreted 7411A program had to be modified to accomplish this. The 7411B uses Fluke Compiled BASIC and the same capability is obtained during configuration.

COMPUTER-AIDED CALIBRATION

The Fluke 7411B Calibration Software package provides automated calibration of meters and oscilloscopes and other dc and low-frequency instruments. The 7411B uses the touch-sensitive screen of the Fluke 1722A Instrument Controller, and can be used with a calibration cluster or automated calibration workstations. The 7411B provides calibration database management and report generation and can be expanded as you upgrade your system.

The 7411B also comes with a library of calibration procedures. You can use these procedures to calibrate meters and oscilloscopes of major manufacturers. You can also edit these procedures to fit your philosophy, or you can write your own custom procedures.

With the 7411B Calibration Software and 7422A Control and Software Package, you have the capability to:

- Write or modify a procedure
- Calibrate and/or verify an instrument
- Maintain a calibration history database
- List results
- List procedures

Depending on your application, the 7411B software configures to a 7404A, 7404B, 7409A, 7449A, or user defined system, as well as a 7405A, 7410A, or A123 Automated Calibration Workstation. Installation notes for these models are provided in the following sections of this manual:

- Installing a 7404A
- Installing a 7404B
- Installing a 7409A
- Installing a 7449A
- Installing a User-Defined System
- Workstation Installation

Automated Calibration System

In the context of this manual, the generic terms "automated calibration system" or "system" are used to refer to either a Calibration Cluster or Calibration Workstation. These terms are defined below.

Calibration Clusters

Computer-aided calibration clusters are automated combinations of calibration instruments controlled by the IEEE-488 bus. A cluster is usually not rack mounted and is under informal configuration control. A cluster can reside on a benchtop or on a mobile cart. With the 7411B software, you can define the instruments you want to automate. As an example, refer to Figure 4-1, Sample Configurations and System Expansion, for the selection of instruments you want to automate. Use this diagram with the 7411B software when you want to transform instruments from stand-alone manual mode to full automation under the control of the Fluke 1722A Instrument Controller.

Automated Calibration Workstations

An automated calibration workstation is a rack mounted collection of calibration instruments. The rack of

equipment is assigned a model number by its manufacturer, and is usually assigned a single property tag by its user. Fluke Automated Calibration Workstations allow you to select the instrument combination necessary to automate your calibration workstation. Fluke workstations can be configured to calibrate most oscilloscopes and meters.

The 7411B can be used to calibrate both manually operated and IEEE-488 bus controlled instruments. It automates the following calibration functions when the Unit Under Test (UUT) is manually operated.

- Input of Operator Name
- Operator Prompt
- Stimulus Control
- UUT Evaluation
- Report Printout
- Data Storage

The 7411B software with a workstation or instrument cluster automates the following functions when the UUT is controlled by the IEEE-488 bus:

- Input of Operator Name
- Operator Prompt
- UUT Setup
- Stimulus Control
- UUT Response
- UUT Evaluation
- UUT Software Calibration
- Report Printout
- Data Storage

The operation of a 7411B based system is described in the Operator Manual. An introduction to procedure writing is given in the Introductory Training Manual, and complete details of all of the functions available

to a procedure writer are provided in the Procedure Writing Manual. The Configuration Manual describes several typical 7411B based systems and has detailed information on how to configure the 7411B for use with specific equipment.

Section 3
Installation and Application Notes

INTRODUCTION

This section provides information that can be used as a guide for configuring, installing and using a 7411B based calibration system. The flexibility of the 7411B means that there are a great many possible permutations of system configurations. Several popular configurations are discussed in the pages that follow. You can adapt the information given on these systems to your specific configuration, if it is different from the examples.

The following configurations are discussed:

Calibration Clusters

- o 7404A
- o 7404B
- o 7409A
- o 7449A
- o User Defined Systems

Calibration Workstations

- o 7405A
- o 7410A
- o A123-CO-nn and A123-PE-nn
- o Combined 7405A/7410A
- o Other Workstations

Calibration Systems with Winchester Disk Option

The Winchester Disk which is connected to the IEEE-488 bus impacts the installation of the calibration system.

Calibration Systems with Bar Code Reader

Any calibration system can be equipped with a bar code reader for quick retrieval and accurate use of calibration procedures.

Information Provided for Winchester Disk Option

This manual contains information on how to add the Winchester Disk option to an existing Calibration System or to install a new system with Winchester Disk.

Information Provided for installing a Bar Code Reader

This manual provides information to install a Bar Code Reader to any of the calibration systems.

Information Provided for Calibration Clusters

The user is responsible for installing a Calibration Cluster. So a system description is given for them, accompanied by a block diagram and a tabulation of other useful installation information. A few application notes are included.

Information Provided for Calibration Workstations

Fluke usually installs a Calibration Workstation, so less information is provided for them in this manual than is provided for clusters. The documentation supplied with a workstation, extensively describes their installation and application. This documentation is referenced in the workstation descriptions that follow.

FUNCTIONAL INTEGRATION TESTS (FIT)

The 7404B, 7405A, 7410A and A123 systems are provided with Functional Integration Test (FIT) software. The FITs provided with these systems are used to give a general idea of whether or not the system is functional. This type of test is sometimes called a 'Good Morning' test. The FITs supplied don't test all of the functions, ranges and modifiers of the instruments used in the system. A user can modify these procedures if he or she wishes to test more of an instruments parameters.

PERFORMANCE VERIFICATION (PV or WPV)

The 7405A and some A123 systems are provided with Performance Verification software. The purpose of this software is to prove that the system meets its specifications. External standards are used in conjunction with this software to test the system. A user can write his or her own performance verification procedure in order to test the performance of a system that does not include a Fluke supplied PV or WPV.

INTRODUCTION

This section provides general information for the 7404A system. This section contains a description of the relationship between hardware and software in the 7404A system, shipping information, and system setup procedures.

7404A SYSTEM DESCRIPTION

The 7404A System is a calibration cluster designed to calibrate analog and digital instruments that measure voltage, current, and resistance. The 7404A contains hardware and software components whose integrated functions establish its performance. A 7404A can be installed on a bench top or on a mobile cart.

Each system includes a Fluke 1722A Instrument Controller, 5100B Calibrator, AC Divider, and the Operator's Aid. The output stimulus range of the basic system can be expanded by the use of the optional 5205A Power Amplifier and/or the 5220A Transconductance Amplifier. Figure 3-1 illustrates the 7404A System in block diagram form.

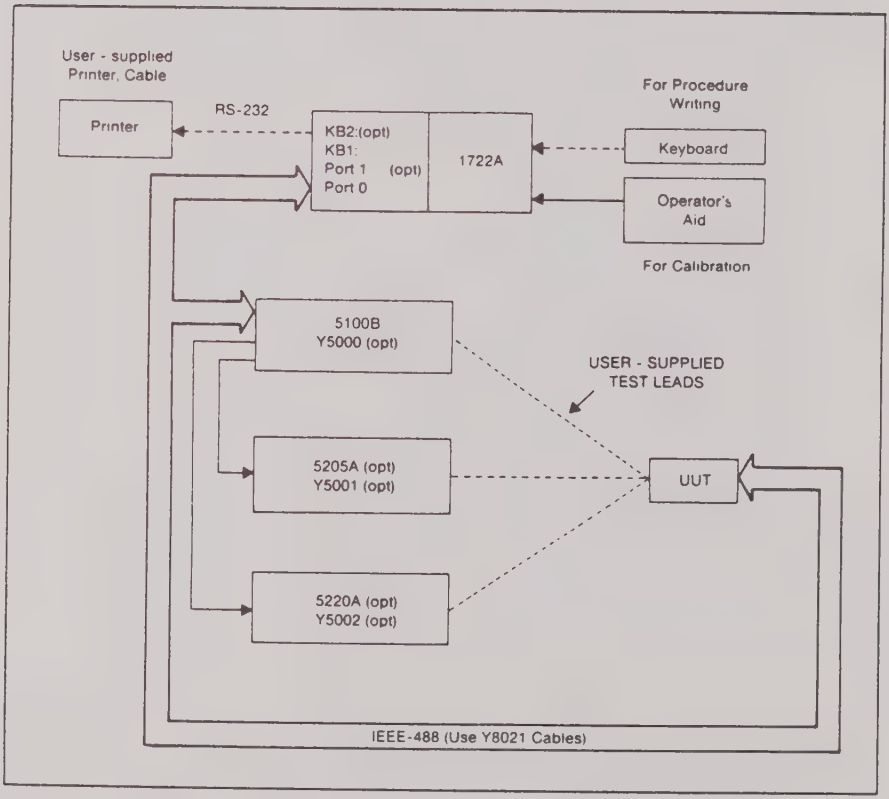


Figure 3-1. 7404A Block Diagram

The 1722A Instrument Controller uses the 7411B Software to guide the operator through the calibration process. The 7411B Software is also used by the 1722A to control all of the hardware within the 7404A System. The use of the 7404A system is simplified by the Controller's Touch Sensitive Display, which allows you to respond to displayed messages by touching the appropriate screen location. A removable keyboard on the 1722A prevents unauthorized entry into the 7411B Software.

The 5100B Calibrator is the primary source of stimuli in the 7404A System. The 5100B provides the voltage, current, or resistance needed to calibrate digital multimeters (DMMs), volt-ohm meters (VOM)s, vacuum tube volt meters (VTVMs), and other dc and low frequency instruments.

The 5205A Power Amplifier and the 5220A Transconductance Amplifier options increase the stimulus range of the 7404A system. The 5205A Power Amplifier provides higher ac or dc power stimuli than the 5100B. The 5205A also provides 100V to 1100V ac voltage above 1 kHz to 50 kHz. The 5220A provides a 20A ac and dc current range.

The AC Divider is a small rectangular box that plugs directly into the 5100B Calibrator. The Divider is attached to the Unit Under Test (UUT) with an included BNC cable. The AC Dividers 1000:1 division ratio divides the 5100B's 50 Hz to 50 kHz direct outputs of 0.2V to 199.999V to provide a low-noise, high-accuracy input of 200 uV to 199.999 mV to the UUT.

The Operator's Aid is a handheld device that provides another way of responding to messages that appear on the Controller's display. The Operator's Aid is described under the heading, The Operator's Aid, in Section 2 of the 7411B Operator Manual.

APPLICATION NOTES

The 7404A can be used in an ambient temperature of 18 to 28°C without derating its specifications. The 7404A has a 2-hour warm-up time in this range of ambient temperatures. When the 7404A is used in a mobile application where power is intermittently removed, the warm-up time of the 7404A is 2 minutes on for every minute off (up to two hours), provided the ambient temperature remains within the 18 to 20oC range.

The calibration adjustments for the instruments in the 7404A are accomplished separately according to the instruction manual procedures for the individual instruments. A Performance Verification procedure is not available for the 7404A.

A Functional Integration Test (FIT) is not provided for the 7404A.

UNPACKING AND INSTALLING THE 7404A

The following paragraphs describe the major assembly steps for a 7404A ordered from the factory. This material should be read and followed carefully for personnel safety and to avoid possible damage to equipment.

You may wish to configure a 7404A from equipment you already own in conjunction with upgrade kits from Fluke. If so, you can select and use applicable information from the following paragraphs as helpful examples to guide you in this effort.

Unpacking the 7404A

The elements of a 7404A system are shipped in several containers. Each hardware model is shipped in its own container(s) along with the instruction manual(s) and any applicable accessories. Check to make sure that you have received all of the following items:

- 1722A Instrument Controller with 72xxA-007 512K RAM expansion board installed and with keyboard.
- 7411B Calibration Software package.
- 5100B Calibrator with 5100A-05 IEEE-488 interface installed.
- 7400A-997 Operator's Aid.
- 7405A-5207 AC Divider.
- One Y8021 IEEE-488 Cable (1 meter length).
- All other instruments and options you may have ordered in addition to the 7404A.

In addition, inspect each container (and those of any options ordered) against its own shipping order, which should be attached to the container. Also inspect for any possible damage that may have occurred during shipment. Immediately report any damage to the shipper. Any discrepancies should be reported directly to the local sales or service office of the John Fluke Mfg. Co., Inc.

Installing the System

WARNING

TO PREVENT ELECTRICAL SHOCK HAZARD, MAKE THE FOLLOWING CONNECTIONS BEFORE ENERGIZING ANY OF THE SYSTEM'S INSTRUMENTS.

Use the following procedure to ensure that the 7404A System is properly set up. Table 3-1 provides information that can be used to help you set the address switches and provide space and power for your 7404A.

1. Verify the contents of your System against the checklist given above.

2. Set the 5100B IEEE-488 address to 4. (Refer to the 5100B Instruction Manual for this procedure.)

Table 3-1. Setting Up the 7404A System

MODEL	IEEE BUS ADDRESS	POWER(1) WATTS	HEIGHT INCHES (MM)	DEPTH INCHES (MM)	WEIGHT(2) POUNDS (Kg)
Computation and Control					
1722A	NA	175	5.25 (13.3)	21.5 (54.6)	42 (19)
Meter Calibration Stimulus					
5100B	4	220	8.75 (22.2)	23.75 (60.3)	77 (35)
5220A (option)	-	300	7.0 (17.8)	22.0 (55.9)	50 (22.7)
5205A (option)	-	1630	10.5 (26.6)	24.75 (62.9)	125 (56.8)

NOTES:
1. System power is the sum of the power for all devices.
2. System weight is the sum of the weights of all devices.
3. All instruments are 17 inches (432 mm) wide.

NOTE

Be sure to cycle the power for the 5100B after you change its address switch.

3. Connect the Y8021 IEEE-488 Interface cable between the IEEE-488 Interface Port 0 on the rear panel of the 1722A and the IEEE-488 Interface port on the rear panel of the 5100B.

NOTE:

The IEEE-488 connectors on the Y8021 connectors can be stacked on each other and can also be daisy chained from the 5100B to other instruments that you may add to the 7404A.

NOTE FOR 7411B SYSTEMS WITH THE WINCHESTER DISK OPTION:

The Winchester Model 1765 B/10 or 1765B/20 (Bering) disk must be connected to the IEEE-488 bus Port 0 of the 1722A controller. Verify that the boot ROM delivered with the Winchester disk is version 1.3 or higher. FDOS version 1.6 or higher should be used.

Winchester Disks Models 1765A/AA and 1765A/AB (Xebex) are not supported and require a special version of the 7411B software.

4. If present, connect the 5205A or 5220A per the instructions supplied with the Y5000 Interface kit.

5. Set the power switches on the individual instruments to energize these instruments. If your System contains a 5205A or 5220A, energize these instruments before energizing the 5100B.

NOTES:

1. The 1722A and 5100B in the 7404A provide an internal self test upon power-up. Refer to the instruction manuals for these instruments if any problems arise during the self tests.

2. If you supply a printer for the 7404A, connect it to the KB1: RS-232 port 0 on the rear of the 1722A. The STRTUP.CMD and COMMND.INT software command files on 7411B software disk 1 and 2 may need to be modified in order to use the printer. For more information, refer to "Adding a Printer" in the section, "Configuring Your 7411B", in this manual.

3. If you use the bar code reader feature in a 7411B systems, connect the bar code reader to KB2: of the 1722A controller, which is the RS-232 connection on the optional IEEE-488 bus card (Port 1). The bar code reader should be set as defined in the STRTUP.CMD and COMMND.INT files. Refer to the information on Adding a Bar Code Reader to Your System.

4. A Functional Integration Test (FIT) is not provided for the 7404A.

5. A Performance Verification (PV) procedure is not available for the 7404A.

INTRODUCTION

This section provides general information for the 7404B system. This section contains a description of the relationship between hardware and software in the 7404B system, shipping information and system setup procedures.

7404B SYSTEM DESCRIPTION

The 7404B system is a calibration cluster designed to calibrate analog and digital instruments that measure voltage, current, and resistance. The 7404B contains hardware and software components whose integrated functions establish its performance. A 7404B can be installed on a bench top or on a mobile cart.

Each system includes a Fluke 1722A Instrument Controller, 5100B Calibrator, 8506A Digital Multimeter, an Accuracy Enhancement Cable, AC Divider, and the Operator's Aid. The output stimulus range of the basic system can be expanded by the use of the optional 5205A Power Amplifier and/or the 5220A Transconductance Amplifier. Figure 3-2 illustrates the 7404B system in block diagram form.

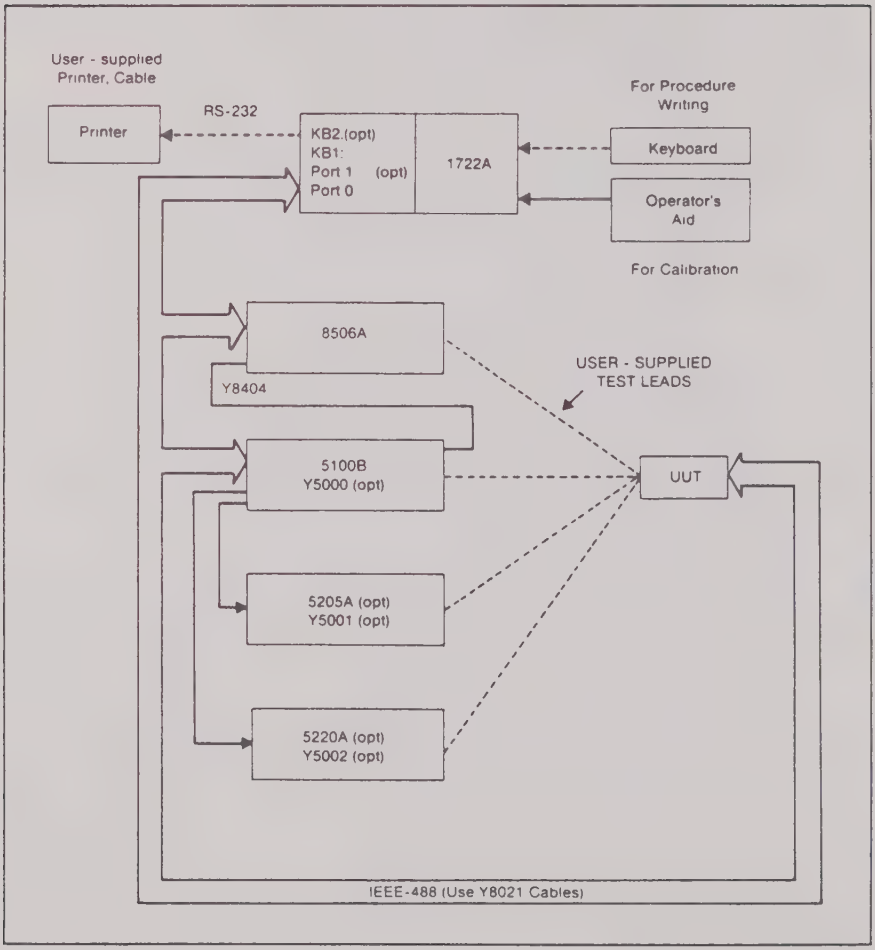


Figure 3-2. 7404B Block Diagram

The 1722A Instrument Controller uses the 7411B Software to guide the operator through the calibration process. The 7411B software is also used by the 1722A to control all of the hardware within the 7404B system. The use of the 7404B system is simplified by the Controller's Touch Sensitive Display, which allows you to respond to displayed messages by touching the appropriate screen location. A removable keyboard on the 1722A prevents unauthorized entry into the 7411B software.

The 5100B Calibrator is the primary source of stimuli in the 7404B system. The 5100B provides the voltage, current, or resistance needed to calibrate DMMs, VOMs, VTVMs, and other dc and low frequency instruments.

The 5205A Power Amplifier and the 5220A Transconductance Amplifier options increase the stimulus range of the 7404B system. The 5205A Power Amplifier provides higher ac or dc power stimuli than the 5100B. The 5205A also provides 100V to 1100V ac voltage above 1 kHz to 50 kHz. The 5220A provides a 20A ac and dc current range.

The front inputs of the 8506A Digital Multimeter provide a measurement port for the 7404B system. The rear inputs of the 8506A are used in conjunction with the Accuracy Enhancement Cable to improve the accuracy of the direct and alternating voltage stimuli of the 5100B. The 7411B supports the use of the mutually-exclusive ohms and current options for the 8506A. However, the 8506A in the basic 7404B does not include either of these options.

The AC Divider is a small rectangular box that plugs directly into the 5100B Calibrator. The Divider is attached to the Unit Under Test (UUT) with an included BNC cable. The AC Dividers 1000:1 division ratio divides the 5100B's 50 Hz to 50 kHz direct outputs of 0.2V to to 199.999V to provide a low noise, high accuracy input of 200 uV to 199.999 mV to the UUT.

The Operator's Aid is a handheld device that provides another way of responding to messages that appear on the Controller's display. The Operator's Aid is described under the heading, The Operator's Aid, in Section 2 of the 7411B Operator Manual.

APPLICATION NOTES

The 7404B can be used in an ambient temperature of 18 to 28°C without derating its specifications. The 7404B has a 2-hour warm-up time in this range of ambient temperatures. When the 7404B is used in a mobile application where power is intermittently removed, the warm-up time of the 7404B is 2 minutes on for every minute off (up to two hours), provided the ambient temperature remains within the 18 to 28oC range.

The calibration adjustments for the instruments in the 7404B are accomplished separately according to the instruction manual procedures for the individual instruments. A Performance Verification procedure is not available for the 7404B.

A Functional Integration Test (FIT) is provided for the 7404B. The 7404B FIT is designed to quickly test whether or not the major elements of the 7404B are functional. The FIT does not verify the performance of the 7404B, and does not test all combinations of ranges and functions of the 7404B. The 7404B FIT can be user edited to conform to the test philosophy of the user.

UNPACKING AND INSTALLING THE 7404B

The following paragraphs describe the major assembly steps for a 7404B ordered from the factory. This material should be read and followed carefully for personnel safety and to avoid possible damage to equipment.

You may wish to assemble a 7404B from equipment you already own in conjunction with upgrade kits from Fluke. If so, you can select and use applicable information from the following paragraphs as helpful examples to guide you in this effort.

Unpacking the 7404B

The 7404B system is shipped in several containers. Each hardware model is shipped in its own container(s) along with its instruction manual(s) and any applicable accessories. Check to make sure that you have received all of the following items:

- 1722A Instrument Controller with 72xxA-007 512K RAM expansion board installed and with keyboard.
- 7411B Calibration Software package.
- 5100B Calibrator with 5100A-05 IEEE-488 interface installed.
- 8506A Digital Multimeter with 85xxA-05 IEEE-488 interface installed.
- 7400A-997 Operator's Aid.
- 7405A-5207 AC Divider.
- Three Y8021 IEEE-488 Cables (1 meter length).
- Y84004 Analog Accuracy Enhancement Cable.
- All other instruments and options you may have ordered in addition to the 7404B.

In addition, inspect each container (and those of any options ordered) against its own shipping order which

should be attached to the container. Also inspect for any possible damage that may have occurred during shipment. Immediately report any damage to the shipper. Any discrepancies should be reported directly to the local sales or service office of the John Fluke Mfg. Co., Inc.

Installing the 7404B

WARNING

TO PREVENT ELECTRICAL SHOCK HAZARD, MAKE THE FOLLOWING CONNECTIONS BEFORE ENERGIZING ANY OF THE SYSTEM'S INSTRUMENTS.

Use the following procedure to ensure that the 7404B System is properly set up. Table 3-2 provides information that can be used to help you set the address switches and provide space and power for your 7404B.

1. Verify the contents of your System against the checklist given above.

2. Set the 5100B IEEE-488 address to 4. (Refer to the 5100B Instruction Manual for this procedure.)

3. Set the 8506A IEEE-488 address to 8. (Refer to the 8506A Instruction Manual for this procedure.)

NOTE

Be sure to cycle the power for the 5100B and 8506A after you change their address switches.

4. Connect the Y8021 IEEE-488 Interface cables between the following points:

   a. IEEE-488 Interface Port 0 on the rear panel of the 1722A and the IEEE-488 Interface port on the rear panel of the 5100B.

b. IEEE-488 Interface Port 0 on the rear panel of the 1722A and the IEEE-488 Interface port on the rear panel of the 8506A.

Table 3-2. Setting Up the 7404B System

MODEL	IEEE BUS ADDRESS	POWER(1) WATTS	HEIGHT INCHES (MM)	DEPTH INCHES (MM)	WEIGHT(2) POUNDS (Kg)
Computation and Control					
1722A	NA	175	5.25 (13.3)	21.5 (54.6)	42 (19)
Meter Calibration Stimulus					
5100B	4	220	8.75 (22.2)	23.75 (60.3)	77 (35)
5220A (Option)	-	300	7.0 (17.8)	22.0 (55.9)	50 (22.7)
5205A (Option)	-	1630	10.5 (26.6)	24.75 (62.9)	125 (56.8)
Measurement					
8506A	8	50	5.25 (13.3)	16.75 (42.5)	31 (14.1)

NOTES:
1. System power is the sum of the power for all devices.
2. System weight is the sum of the weights of all devices.
3. All instruments are 17 inches (432 mm) wide.

NOTE

The IEEE-488 connectors on the Y8021 connectors can be stacked on each other, and can also be daisy chained from the 5100B to 8506A, if this is preferred.

NOTE FOR 7411B SYSTEMS WITH THE WINCHESTER DISK OPTION:

The Winchester Model 1765 B/10 or 1765B/20 (Bering) disk must be connected to the IEEE-488 bus Port 0 of the 1722A controller. Verify that the boot ROM delivered with the Winchester disk is version 1.3 or higher. FDOS version 1.6 or higher should be used.

Winchester Disks Models 1765A/AA and 1765A/AB (Xebex) are not supported and require a special version of the 7411B software.

5. Connect the Y8404 Analog Accuracy Enhancement Cable between the 5100B and the 8506A as follows:

   a. Install the gray box end of the cable to the rear panel input terminal of the 8506A.

   b. Tighten the connector screw to secure the connector box to the 8506A.

   c. Plug the 5100B connector end of the cable into the front panel output connector of the 5100B.

6. If present, connect the 5205A or 5220A per the instructions supplied with the Y5000 Interface kit.

7. Set the power switches on the individual instruments to energize these instruments. If your System contains a 5205A or 5220A, energize these instruments before energizing the 5100B.

NOTES:

1. The 1722A, 8506A, and 5100B in the 7404B provide an internal self test upon power-up. Refer to the instruction manuals for these instruments if any problems arise during the self tests.

2. If you supply a printer for the 7404B, connect it to the KB1: RS-232 port 0 on the rear of the 1722A. The STRTUP.CMD and COMMND.INT software command files on 7411B software disk 1 and 2 may need to be modified in order to use the printer. For more information, refer to "Adding a Printer" in the section, "Configuring Your 7411B", in this manual

3. If you use the bar code reader feature in a 7411B systems, connect the bar code reader to KB2: of the 1722A controller, which is the RS-232 connection on the optional IEEE-488 bus card (Port 1). The bar code reader should be set as defined in the STRTUP.CMD and COMMND.INT files. Refer to the information on Adding a Bar Code Reader to Your System.

4. If you have configured the 7411B software for use in a 7404B, the default capabilities of the software include the ability to measure resistance and current even if these options are not included in the 8506A.

5. You can edit the Functional Integration Test (FIT) for the 7404B to suit your needs.

6. A Performance Verification (PV) procedure is not available for the 7404B.

INTRODUCTION

This section provides general information for the 7409A System. This section contains a description of the relationship between hardware and software in the 7409A System, shipping information, and system setup procedures.

7409A SYSTEM DESCRIPTION

The 7409A System is a calibration cluster designed to calibrate oscilloscopes. The 7409A contains hardware and software components whose integrated functions establish its performance. A 7409A can be installed on a bench top or on a mobile cart.

Each system includes a Fluke 1722A Instrument Controller, a Tektronix(R)* CG5001 Programmable Calibrator Generator for oscilloscopes, and the Operator's Aid. Figure 3-3 illustrates the 7409A System in a block diagram form.

The 1722A Instrument Controller uses the 7411B Software to guide the operator through the calibration process. The 7411B Software is also used by the 1722A to control the hardware within the 7409A System. The use of the 7409A system is simplified by the Controller's Touch Sensitive Display, which allows you to respond to displayed messages by touching the appropriate screen location. A removable keyboard on the 1722A prevents unauthorized entry into the System Software.

---

* Tektronix is a registered trademark of Tektronix, Inc.

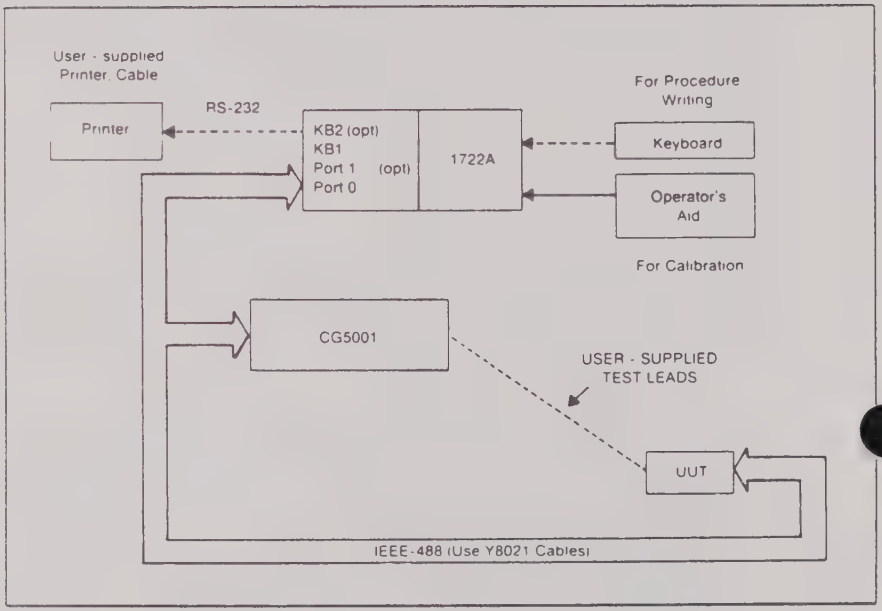


Figure 3-3. 7409A Block Diagram

The CG5001 is the primary source of stimulus in the 7409A system. The CG5001 provides square waves and pulses for amplitude and time calibration, and can also calibrate the calibrator output port of an oscilloscope.

The Operator's Aid is a handheld device that provides another way of responding to messages that appear on the Controller's display. The Operator's Aid is described under the heading, The Operator's Aid, in Section 2 of the 7411B Operator Manual.

APPLICATION NOTES

The 7409A can be used in an ambient temperature of 18 to 28°C without derating its specifications. The 7409A has a 2-hour warm-up time in this range of ambient temperatures. When the 7409A is used in a mobile application where power is intermittently removed, the warm-up time of the 7409A is 2 minutes on for every minute off (up to two hours), provided the ambient temperature remains within the above range.

The calibration adjustments for the CG5001 in the 7409A are accomplished separately according to the instruction manual procedure for the CG5001. A Performance Verification procedure is not available for the 7409A.

A Functional Integration Test (FIT) is not provided for the 7409A.

The user can expand the capabilities (output stimulus range) of the 7409A by using a Fluke synthesized signal generator such as the 6060B. The 6060B is used for bandwidth and trigger level calibration.

UNPACKING AND INSTALLING THE 7409A

The following paragraphs describe the major assembly steps for a 7409A. This material should be read and followed carefully for personnel safety and to avoid possible damage to equipment.

Unpacking the 7409A

The elements of a 7409A system are shipped in several containers. Each hardware model is shipped in its own container(s) along with its instruction manual(s) and any applicable accessories. Check to make sure that you have received all of the following items:

- 1722A Instrument Controller with 72xxA-007 512K RAM expansion board installed and with keyboard.
- 7411B Calibration Software package.
- CG5001 Calibrator installed in a TM 5006 Mainframe and with Pulse and Comparator Heads.
- 7400A-997 Operator's Aid.
- One Y8021 IEEE-488 Cables (1 meter length).
- All other instruments and options you may have ordered in addition to the 7409A.

In addition, inspect each container (and those of any options ordered) against its own shipping order, which should be attached to the container. Also inspect for any possible damage that may have occurred during shipment. Immediately report any damage to the shipper. Any discrepancies should be reported directly to the local sales or service office of the John Fluke Mfg. Co., Inc.

Installing the 7409A

WARNING

TO PREVENT ELECTRICAL SHOCK HAZARD, MAKE THE FOLLOWING CONNECTIONS BEFORE ENERGIZING ANY OF THE SYSTEM'S INSTRUMENTS.

Use the following procedure to ensure that the 7409A System is properly set up. Table 3-3 provides information that can be used to help you set the address switches and provide space and power for your 7409A.

1. Verify the contents of your System against the checklist given above.

2. Set the CG5001 IEEE-488 address to 28. (Refer to the CG5001 Instruction Manual for this procedure.)

Table 3-3 Setting Up the 7409A System

MODEL	IEEE BUS ADDRESS	POWER(1) WATTS	HEIGHT INCHES (MM)	DEPTH INCHES (MM)	WEIGHT(2) POUNDS (Kg)
Computation and Control					
1722A	NA	175	5.25 (13.3)	21.5 (54.6)	42 (19)
Oscilloscope Calibration Stimulus					
CG 5001	28	650	7.0 (17.8)	19.2 (48.7)	28 (12.7)

NOTES:
1. System power is the sum of the power for all devices.
2. System weight is the sum of the weights of all devices.
3. All instruments are 17 inches (432 mm) wide.

NOTE

Be sure to cycle the power for the CG5001 after you change its address switch.

3. Connect the Y8021 IEEE-488 Interface cable between the IEEE-488 Interface Port 0 on the rear panel of the 1722A and the IEEE-488 Interface port on the rear panel of the CG5001.

NOTE

The IEEE-488 connectors on the Y8021 connectors can be stacked on each other and can also be daisy chained from the CG5001 to other instruments you may add to the 7409A.

NOTE FOR 7411B SYSTEMS WITH THE WINCHESTER DISK OPTION:

The Winchester Model 1765 B/10 or 1765B/20 (Bering) disk must be connected to the IEEE-488 bus Port 0 of the 1722A controller. Verify that the boot ROM delivered with the Winchester disk is version 1.3 or higher. FDOS version 1.6 or higher should be used.

Winchester Disks Models 1765A/AA and 1765A/AB (Xebex) are not supported and require a special version of the 7411B software.

4. Set the power switch on the CG5001 to energize it.

NOTES:

1. The 1722A and CG5001 in the 7409A provide an internal self test upon power-up. Refer to the instruction manuals for these instruments if any problems arise during the self tests.

2. If you supply a printer for the 7409A, connect it to the KB1: RS-232 port on the rear of the 1722A. The STRTUP.CMD and COMMND.INT software command files on 7411B software disk 1 and 2 may need to be modified in order to use the printer. For more information, refer to "Adding a Printer" in the section, "Configuring Your 7411B", in this manual.

3. If you use the bar code reader feature in a 7411B systems, connect the bar code reader to KB2: of the 1722A controller, which is the RS-232 connection on the optional IEEE-488 bus card (Port 1). The bar code reader should be set as defined in the STRTUP.CMD and COMMND.INT files. Refer to the information on Adding a Bar Code Reader to Your System.

4. A Functional Integration Test (FIT) and Workstation Performance Verification Test are not available for the 7409A.

INTRODUCTION

This section provides general information for the 7449A system. This section contains a description of the relationship between hardware and software in the 7449A System, shipping information, and system setup procedures.

7449A SYSTEM DESCRIPTION

The 7449A System is a calibration cluster designed to calibrate oscilloscopes, DMMs, VOMs, VTVMs, and other similar instruments. The 7449A contains hardware and software components whose integrated functions establish its performance. A 7449A can be installed on a bench top or on a mobile cart.

Each system includes a Fluke 1722A Instrument Controller, 5100B Calibrator, 8506A Digital Multimeter, Accuracy Enhancement Cable, AC Divider, a Tektronix CG5001 Programmable Calibrator Generator for oscilloscope calibrations, and the Operator's Aid. The output stimulus range of the basic system can be expanded by the use of the optional 5205A Power Amplifier and/or the 5220A Transconductance Amplifier. Figure 3-4 illustrates the 7449A System in block diagram form.

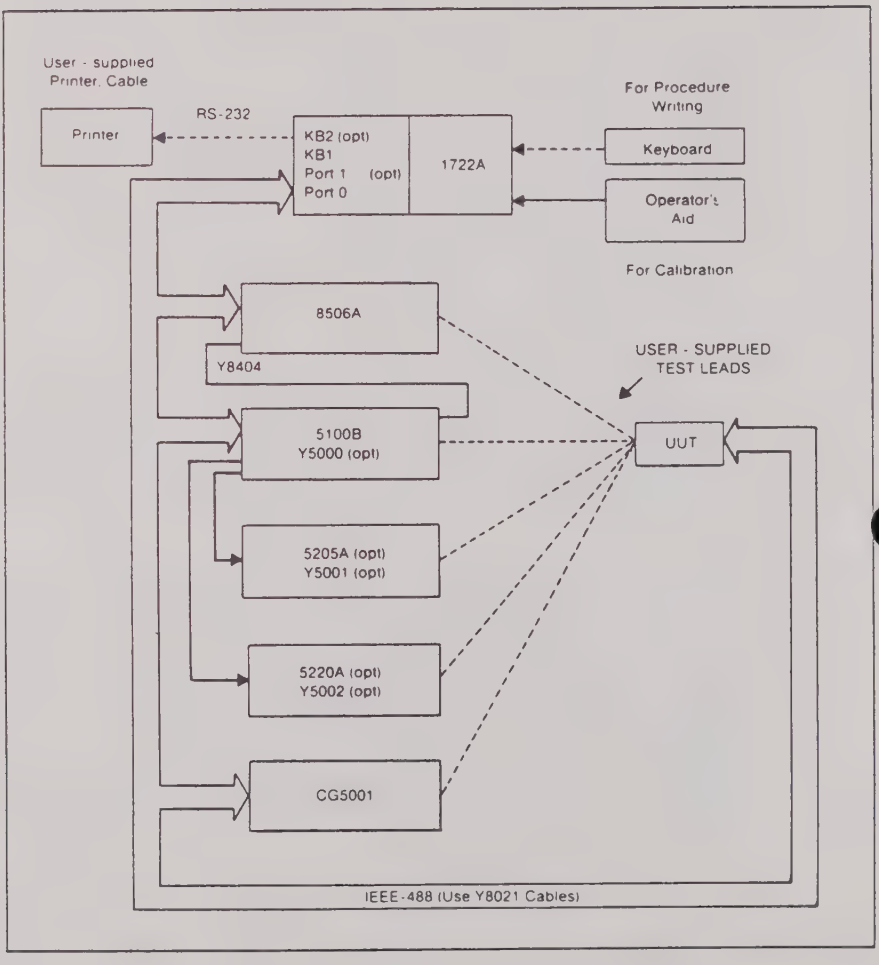


Figure 3-4. 7449A Block Diagram

The 1722A Instrument Controller uses the 7411B Software to guide the operator through the calibration process. The 7411B Software is also used by the 1722A to control all of the hardware within the 7449A System. The use of the 7449A system is simplified by the Controller's Touch Sensitive Display, which allows you to respond to displayed messages by touching the appropriate location. A removable keyboard on the 1722A prevents unauthorized entry into the 7411B Software.

The CG5001 and 5100B Calibrators are the primary source of stimuli in the 7449A System. The CG5001 provides square waves and pulses for amplitude and time calibration. The 5100B provides the voltage, current, or resistance stimulus needed to calibrate DMMs built into oscilloscopes, as well as stand-alone VOMs, VTVMs, and other dc and low frequency instruments.

The 5205A Power Amplifier and the 5220A Transconductance Amplifier options increase the stimulus range of the 7449A system. The 5205A Power Amplifier provides higher ac or dc power stimuli than the 5100B. The 5205A also provides 100V to 1100V ac voltage above 1 kHz to 50 kHz. The 5220A provides a 20A ac and dc current range.

The front inputs of the 8506A Digital Multimeter provide a measurement port for the 7449A system. The rear inputs of the 8506A are used in conjunction with the Accuracy Enhancement Cable to improve the accuracy of the direct and alternating volts stimuli of the 5100B. The CG5001 provides measurement capability to calibrate an oscilloscope calibrator output port.

The AC Divider is a small rectangular box that plugs directly into the 5100B Calibrator. The Divider is attached to the Unit Under Test (UUT) with an included BNC cable. The AC Dividers 1000:1 division ratio divides the 5100B's 50 Hz to 50 kHz direct outputs of 0.2V to 199.999V to provide a low noise, high accuracy input of 200 uV to 199.999 mV to the UUT.

The Operator's Aid is a handheld device that provides another way of responding to messages that appear on the Controller's display. The Operator's Aid is described under the heading, The Operator's Aid, in Section 2 of the 7411B Operator Manual.

APPLICATION NOTES

The 7449A can be used in an ambient temperature of 18 to 28°C without derating its specifications. The 7449A has a 2-hour warm-up time in this range of ambient temperatures. When the 7449A is used in a mobile application where power is intermittently removed, the warm-up time of the 7449A is 2 minutes on for every minute off (up to two hours), provided the ambient temperature remains within the 18 to 28oC range.

The calibration adjustments for the instruments in the 7449A are accomplished separately according to the instruction manual procedures for the individual instruments. A Performance Verification procedure is not available for the 7449A.

A Functional Integration Test (FIT) is not provided for the 7449A.

The user can expand the capabilities of the 7449A by using a Fluke synthesized signal generator such as the 6060B. The 6060B is used for bandwidth and trigger level calibration.

UNPACKING AND INSTALLING THE 7449A

The following paragraphs describe the major assembly steps for a 7449A. This material should be read and followed carefully for personnel safety and to avoid possible damage to equipment.

Unpacking the 7449A

The elements of a 7449 system are shipped in several containers. Each hardware model is shipped in its own container(s) along with its instruction manual(s) and any applicable accessories. Check to make sure that you have received all of the following items:

- 1722A Instrument Controller with 72xxA-007 512K RAM expansion board installed and with keyboard.
- 7411B Calibration Software package.
- 5100B Calibrator with 5100A-05 IEEE=488 interface installed.
- 8506A Digital Multimeter with 85xxA-05 IEEE-488 interface installed.
- CG5001 Calibrator installed in a TM 5006 Mainframe and with Pulse and Comparator Heads.
- 7400A-997 Operator's Aid.
- 7405A-5207 AC Divider.
- Four Y8021 IEEE-488 Cables (1 meter length).
- Y84004 Analog Accuracy Enhancement Cable.
- All other instruments and options you may have ordered in addition to the 7449A.

In addition, inspect each container (and those of any options ordered) against its own shipping order, which should be attached to the container. Also inspect for any possible damage that may have occurred during shipment. Immediately report any damage to the shipper. Any discrepancies should be reported directly to the local sales or service office of the John Fluke Mfg. Co., Inc.

Installing the 7449A

WARNING

TO PREVENT ELECTRICAL SHOCK HAZARD, MAKE THE FOLLOWING CONNECTIONS BEFORE ENERGIZING ANY OF THE SYSTEM'S INSTRUMENTS.

Use the following procedure to ensure that the 7449A System is properly set up. Table 3-4 provides information that can be used to help you set the address switches and provide space and power for your 7449A.

1. Verify the contents of your System against the checklist given above.

2. Set the 5100B IEEE-488 address to 4. (Refer to the 5100B Instruction Manual for this procedure.)

3. Set the 8506A IEEE-488 address to 8. (Refer to the 8506A Instruction Manual for this procedure.)

4. Set the CG5001 address to 28. (Refer to the CG5001 Instruction Manual for this procedure.)

NOTE

Be sure to cycle the power for the 5100B, 8506A, and CG5001 after you change their address switches.

Table 3-4. Setting Up the 7449A System

MODEL	IEEE BUS ADDRESS	POWER(1) WATTS	HEIGHT INCHES (MM)	DEPTH INCHES (MM)	WEIGHT(2) POUNDS (Kg)
Computation and Control					
1722A	NA	175	5.25 (13.3)	21.5 (54.6)	42 (19)
Meter Calibration Stimulus					
5100B	4	220	8.75 (22.2)	23.75 (60.3)	77 (35)
5220A (Option)	-	300	7.0 (17.8)	22.0 (55.9)	50 (22.7)
5205A (Option)	-	1630	10.5 (26.6)	24.75 (62.9)	125 (56.8)
Oscilloscope Calibration Stimulus					
CG 5001	28	650	7.0 (17.8)	19.2 (487.7)	28 (12.7)
Measurement					
8506A	8	50	5.25 (13.3)	16.75 (42.5)	31 (14.1)

NOTES:
1. System power is the sum of the power for all devices.
2. System weight is the sum of the weights of all devices.
3. All instruments are 17 inches (432 mm) wide.

5. Connect the Y8021 IEEE-488 Interface cables between the following points:

   a. IEEE-488 Interface Port 0 on the rear panel of the 1722A and the IEEE-488 Interface port on the rear panel of the 5100B.

   b. IEEE-488 Interface Port 0 on the rear panel of the 1722A and the IEEE-488 Interface port on the rear panel of the 8506A.

   c. IEEE-488 Interface Port 0 on the rear panel of the 1722A and the IEEE-488 Interface port on the rear panel of the TM 5006.

NOTE

The IEEE-488 connectors on the Y8021 connectors can be stacked on each other and can also be daisy chained from the 5100B to 8506A to CG5001, if this is preferred.

NOTE FOR 7411B SYSTEMS WITH THE WINCHESTER DISK OPTION:

The Winchester Model 1765 B/10 or 1765B/20 (Bering) disk must be connected to the IEEE-488 bus Port 0 of the 1722A controller. Verify that the boot ROM delivered with the Winchester disk is version 1.3 or higher. FDOS version 1.6 or higher should be used.

Winchester Disks Models 1765A/AA and 1765A/AB (Xebex) are not supported and require a special version of the 7411B software.

6. Connect the Y8404 Analog Accuracy Enhancement Cable between the 5100B and the 8506A as follows:

   a. Install the gray box end of the cable to the rear panel input terminal of the 8506A.

b. Tighten the connector screw to secure the connector box to the 8506A.

c. Plug the 5100B connector end of the cable into the front panel output connector of the 5100B.

7. If present, connect the 5205A or 5220A per the instructions supplied with the Y5000 Interface kit.

8. Set the power switches on the individual instruments to energize these instruments. If your System contains a 5205A or 5220A, energize these instruments before energizing the 5100B.

NOTES:

1. Most of the instruments in the 7449A provide an internal self test upon power-up. Refer to the individual instruction manuals for these instruments if any problems arise during the self tests.

2. If you supply a printer for the 7449A, connect it to the KB1: RS-232 port 0 on the rear of the 1722A. The STRTUP.CMD and COMMND.INT software command files on 7411B software disk 1 and 2 may need to be modified in order to use the printer. For more information, refer to "Adding a Printer" in the section, "Configuring Your 7411B", in this manual.

3. If you use the bar code reader feature in a 7411B systems, connect the bar code reader to KB2: of the 1722A controller, which is the RS-232 connection on the optional IEEE-488 bus card (Port 1). The bar code reader should be set as defined in the STRTUP.CMD and COMMND.INT files. Refer to the information on Adding a Bar Code Reader to Your System.

4. If you have configured the 7411B as a 7449A, the default capabilities of the software will include the ability to measure resistance and current even if these options are not included in the 8506A.

5. A Functional Integration Test (FIT) is not available for the 7449A.

6. A Performance Verification (PV) procedure is not available for the 7449A.

INTRODUCTION

This section provides general information for installing a User-Defined System (UDS). This section contains a description of the relationship between hardware and software in a typical UDS, and typical system setup procedures.

UDS DESCRIPTION

Overview

A UDS is defined and designed by a user to solve a particular calibration or precision functional test problem. The UDS can range from a calibration cluster to a functional test workstation. For example, a UDS could be configured to test A/D converters or to calibrate oscilloscopes, DMMs, VOMs, VTVMs, and other similar instruments. The integrated functioning of the UDS hardware and software components establish its performance. A UDS may be designed for installation on a bench or on a mobile cart.

A 7411B-based UDS should include a Fluke 1722A Instrument Controller and Operator's Aid. The UDS should also include stimulus and/or measurement instruments selected from Table 3-5. Figure 3-5 is an example of a block diagram for a UDS that uses these instruments.

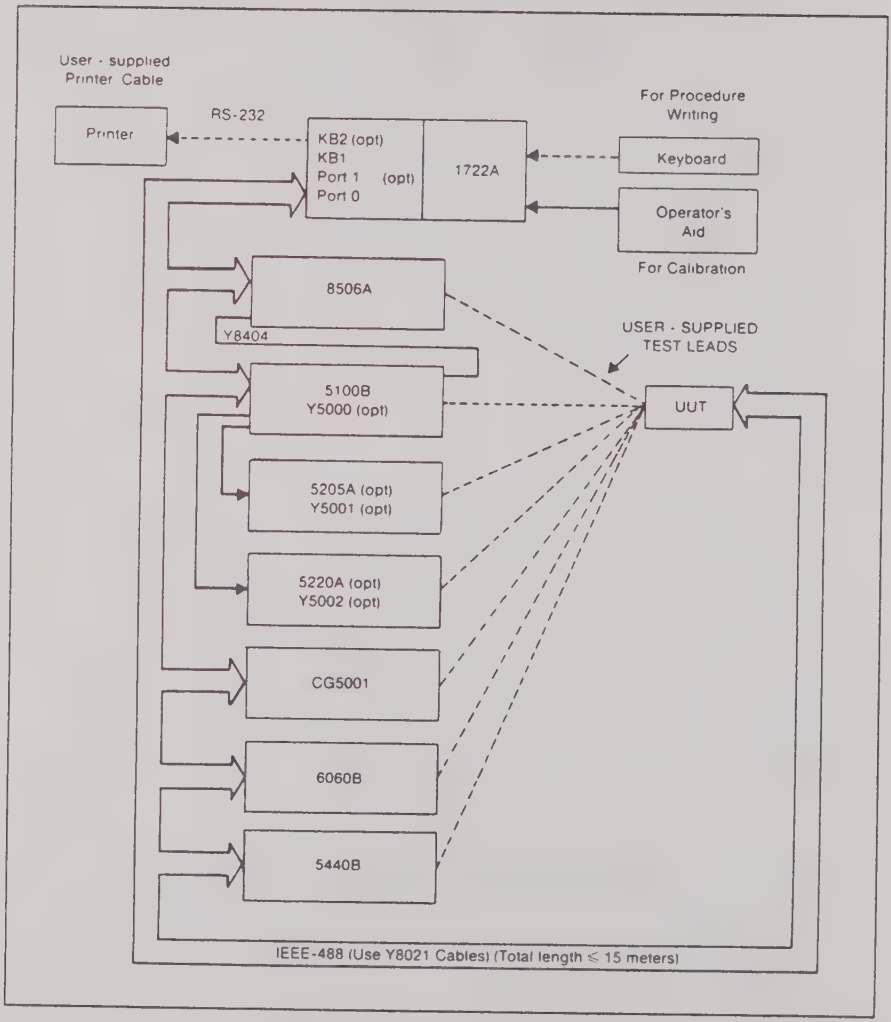


Figure 3-5. User Defined System Sample Block Diagram

Table 3-5. Setting Up a User Defined System

MODEL	IEEE BUS ADDRESS	POWER1 WATTS	INCHES HEIGHT (MM)	INCHES DEPTH (MM)	POUNDS2 WEIGHT (kg)
Computation and Control					
1722A	NA	175	5.25 (13.3)	21.5 (54.6)	42 (19)
Dc and Low Frequency Stimulus					
5100B (5101B)	4	220	8.75 (22.2)	23.75 (60.3)	77 (35)
5440B (5442A)	3	145	8.75 (22.2)	24.0 (60.9)	72 (32.7)
5450A	5	50	3.5 (8.9)	21.75 (55.2)	26 (11.8)
5220A	-	300	7.0 (17.8)	22.0 (55.9)	50 (22.7)
5205A (5215A)	-	1630	10.5 (26.7)	24.75 (62.9)	125 (56.8)
5200A	11	100	7.0 (17.8)	21.75 (55.2)	58 (26.4)
Pulse and Waveform Stimulus					
CG 5001	28	650	7.0 (17.8)	19.2 (48.8)	28 (12.7)
Wavetek 278	22	50	5.25 (13.3)	8.5 (21.6)	6.8 (3.1)

Table 3-5. Setting Up a User Defined System (cont)

MODEL	IEEE BUS ADDRESS	POWER1 WATTS	INCHES HEIGHT (MM)	INCHES DEPTH (MM)	POUNDS2 WEIGHT (kg)
Rf Stimulus					
6011A (6010A)	26	100	5.25 (13.3)	8.5 (21.6)	25 (11.4)
6060A	23	125	5.25 (13.3)	21.5 (54.6)	61 (27.7)
6071A	27	125	5.25 (13.3)	21.5 (54.6)	61 (27.7)
Measurement					
1953A	1	30	3.5 (8.9)	13.5 (34.3)	15 (6.8)
8505A (8502A)	2	50	5.25 (13.3)	16.75 (42.5)	31 (14.1)
8506A	8	50	5.25 (13.3)	16.75 (42.5)	31 (14.1)
8520A	24	50	3.5 (8.9)	18.0 (45.7)	21 (9.5)

Table 3-5. Setting Up a User Defined System (cont)

MODEL	IEEE BUS ADDRESS	POWER1 WATTS	INCHES HEIGHT (MM)	INCHES DEPTH (MM)	POUNDS2 WEIGHT (kg)

NOTES:

1. System power is the sum of the power for all devices
2. System weight is the sum of the weights of all devices.
3. Model numbers in parenthesis can be controlled by the 7411A FSC for the main model number. However, the 7411A FSC does not recognize specification or performance differences between the main instrument and the parenthetical instrument. The user must recognize these differences and compensate for them in the procedures he or she writes or edits.
4. All instruments are 17 inches (432mm) wide, except the 6011A and 278 which are 8.5 inches (216mm) wide.

Computation and Control

The 1722A Instrument Controller uses the 7411B Software to guide the operator through the calibration (or test) process. The 7411B Software is also used by the 1722A to control all of the hardware within the system. The system is simplified by the 1722A Touch Sensitive Display, which allows the user to respond to the messages it displays by touching the appropriate location on the CRT. A removable keyboard on the 1722A prevents unauthorized entry into the 7411B Software.

The Operator's Aid is a handheld device that provides another way of responding to messages that appear on the Controller's display. The Operator's Aid is described under the heading, The Operator's Aid, in Section 2 of the 7411B Operator Manual.

DC and Low-Frequency Stimulus

Dc and low-frequency (to 1MHz) stimulus include Fluke Models 5100B, 5440B, 5450A, 5200A, 5205A, 5215A, and 5220A Calibrators. The 5100B provides the voltage, current, or resistance stimulus needed to calibrate stand-alone VOMs, VTVMs, and other dc and low frequency instruments and devices, as well as DMMs built into oscilloscopes. The 5440B provides precise direct voltages. The 5450A provides precise cardinal-point resistance values. The 5200A is an accurate ac voltage calibrator with a high degree of frequency resolution that can be phase locked to an external source. The 5205A and 5215A are boost voltage power amplifiers for the 5200A, 5100B, and 5440B. The 5220A is a 20A ac/dc transconductance amplifier used with the 5100B.

Pulse and Waveform Stimulus

Tektronix Model CG5001 provides square waves and pulses for amplitude and time calibration of oscilloscopes. Wavetek(R)* Model 278 provides sine, square, triangular, and arbitrary waveform stimulus for test and calibration applications.

RF Stimulus

Fluke Models 6011A, 6060B, 6070A, and 6071A are synthesized signal generators that provide rf stimulus of very high purity and frequency accuracy.

Measurement

Fluke Models 8520A, 8505A, and 8506A are DMMs. The 8520A is a medium-accuracy three-function DMM that measures direct and alternating volts and resistance. The 8505A is a high-accuracy five-function DMM that measures direct and alternating volts, direct and

alternating current, and resistance. The 8506A is a three-function DMM that measures alternating voltage with extremely high accuracy, as well as measuring direct voltage, resistance, and current.

Fluke Model 1953A measures frequency, period, and time.

Application Notes

The instruments listed in Table 5 can be used in an ambient temperature of 18 to 28°C without derating their specifications. Most of the instruments have a 2-hour warm-up time in this range of ambient temperatures. When the instruments are used in a mobile application where their power is intermittently removed, their warm-up time is 2 minutes on for every minute off (up to two hours), provided the ambient temperature remains within the 18 to 28°C range.

The calibration adjustments for these instruments are accomplished separately according to the instruction manual procedures for the individual instruments. The development of a Performance Verification (PV) procedure for a UDS is the responsibility of the user. The development of a Functional Integration Test (FIT) for a UDS is also the responsibility of the user.

INSTALLING A UDS

WARNING

TO PREVENT ELECTRICAL SHOCK HAZARD, MAKE THE FOLLOWING CONNECTIONS BEFORE ENERGIZING ANY OF THE SYSTEM'S INSTRUMENTS.

Use the following general procedure to ensure that a UDS is properly set up. Table 5 provides information

that can be used to help you set the address switches and provide space and power for your UDS.

1. Verify that you have all of the equipment needed to assemble your UDS.

2. Set the IEEE-488 addresses of the individual instruments. (Refer to their instruction manuals for this procedure.)

NOTE

Be sure to cycle the power for the instruments after changing the settings of their address switches.

3. Connect the Y8021 IEEE-488 Interface cables to the instruments and the controller. The IEEE-488 connectors on the Y8021 connectors can be stacked on each other and can also be daisy chained from the 1722A Instrument Controller to the individual instruments.

NOTE FOR 7411B SYSTEMS WITH THE WINCHESTER DISK OPTION:

The Winchester Model 1765 B/10 or 1765B/20 (Bering) disk must be connected to the IEEE-488 bus Port 0 of the 1722A controller. Verify that the boot ROM delivered with the Winchester disk is version 1.3 or higher. FDOS version 1.6 or higher should be used.

Winchester Disks Models 1765A/AA and 1765A/AB (Xebex) are not supported and require a special version of the 7411B software. The Winchester Disk uses IEEE-488 address 6. Any 5200A in the system should be set up for IEEE-488 address 11.

4. Connect the analog cables as needed.

5. Set the power switches on the individual instruments to energize these instruments. If your System contains a 5205A or 5220A, energize these instruments before energizing the 5100B.

NOTES:

1. Many of the instruments listed in Table 3-5 provide an internal self test upon power-up. Refer to the individual instruction manuals for these instruments if any problems arise during the self tests.

2. If you supply a printer for the UDS, connect it to the KB1: RS-232 port 0 on the rear of the 1722A. The STRTUP.CMD and COMMND.INT software command files on 7411B software disk 1 and 2 may need to be modified in order to use the printer. For more information, refer to "Adding a Printer" in the section, "Configuring Your 7411B", in this manual.

3. If you use the bar code reader feature in a 7411B systems, connect the bar code reader to KB2: of the 1722A controller, which is the RS-232 connection on the optional IEEE-488 bus card (Port 1). The bar code reader should be set as defined in the STRTUP.CMD and COMMND.INT files. Refer to the information on Adding a Bar Code Reader to Your System.

TYPES OF WORKSTATIONS

The following generic types of workstations are available from Fluke:

- Standard Workstations
- Custom-Configured Workstations

In addition, users can configure their own workstations or add equipment to the workstations supplied by Fluke.

The information in this section identifies some of the key issues associated with the installation of the various types of workstations. However, this information does not cover all possible system arrangements, so the user is encouraged to use the available Fluke consultation and training to answer questions concerning specific system configurations.

DEFINITIONS

Standard Workstations are calibration systems whose specific configuration, specifications, and deliverables list are all defined by Fluke. Custom-Configured Workstations are calibration systems whose specific configuration, specifications, or deliverables list are each or all negotiated with a specific customer.

The Standard Calibration Workstations are as follows:

- 7405A
- 7410A
- A123-CO-nn (nn is a two-digit number that identifies the specific equipment used in the A123-CO-nn)
- A123-PE-nn (nn is a two-digit number that identifies the specific equipment used in the A123-PE-nn)

Custom-Configured Workstations include:

- Combined 7405A/7410A
- A123s other than the A123-CO-nn or A123-PE-nn
- All other model numbers, including all other A100s

INSTALLING STANDARD WORKSTATIONS

7405A

Installation information for the 7405A is provided in the 7405A System Preparation Manual which is supplied with the 7405A. The System Preparation Manual is located in the binder titled, 7405A Automated Calibration System, Volume 1. The 7405A is normally installed by Fluke.

7410A

Installation information for the 7410A is provided in Fluke Service Information bulletin C0089 which is supplied with the 7410A. The 7410A is normally installed by Fluke.

A123-CO-nn and A123-PE-nn

Installation information for the A123-CO-nn and A123-PE-nn workstations is available in the system specifications and drawing packages supplied with them. The A123-CO-nn and A123-PE-nn are normally installed by Fluke.

INSTALLING CUSTOM WORKSTATIONS

Combined 7405A/7410A

A typical combined 7405A/7410A uses a standard 7410A and a 7405A (without the 74xxA-workstation table and 1722A Instrument Controller). The combined workstation is normally installed by Fluke.

Application Information

Meters and oscilloscopes under calibration are placed on or near the 7410A workstation table. The test interface panels of both the 7405A and 7410A are used. All of the instruments in the composite workstation are under the control of the sole 1722A in the system.

The default for the 7411B ASK FSC (see the headings, "ASK+" and "ASK-", in Section 4 of the 7411B Procedure Writing Manual) must be configured by the user to provide automated messages for either oscilloscopes or meters. All procedures supplied with the 7411B must be edited by the user to conform to the user-selected default for the ASK FSC.

The Functional Integration Test (FIT), also called Functional Self Test (FST), and Workstation Performance Verification (WPV) software routines supplied with the composite system are designed to be run separately for each system. To create a composite FIT or WPV, the user must obtain 7411B source code to modify the BASIC

programs supplied with the systems. The modifications must link the BASIC programs and the procedures into one continuous FIT or WPV.

ALL OTHER WORKSTATIONS

Other workstation models may or may not be installed by Fluke, as negotiated with the user. The installation information for the workstation is supplied according to the negotiation.

Application Information

The default for the 7411B ASK FSC (see the headings, "ASK+" and "ASK-", in Section 4 of the 7411B Procedure Writing Manual) must be configured by the user to provide automated messages for either oscilloscopes or meters. All procedures supplied with the 7411B must be edited by the user to conform to the user-selected default for the ASK FSC.

A Functional Integration Test (FIT) and Workstation Performance Verification Test (WPV) may be supplied with the workstation, as negotiated with the user. These procedures may be edited to conform to the default for the ASK FSC and the laboratory calibration philosophy of the user.

USER-CONFIGURED ARRANGEMENTS

In principle, a user could configure any possible arrangement of workstations and/or clusters. It is beyond the scope of this manual to address all of the issues associated with using the 7411B in these calibration arrangements. However, the following information identifies some of the matters that the user should be aware of when configuring a calibration arrangement.

The default for the 7411B ASK FSC (see the headings, "ASK+" and "ASK-", in Section 4 of the 7411B Procedure

Writing Manual) must be configured by the user to provide automated messages for either oscilloscopes or meters. All procedures supplied with the 7411B must be edited by the user to conform to the user-selected default for the ASK FSC.

The Functional Integration Test (FIT), also called Functional Self Test (FST), and Workstation Performance Verification (WPV) software routines supplied with standard and custom Fluke systems are designed to be run separately for each system. To create a composite FIT or WPV, the user must obtain 7411B source code to modify the BASIC programs supplied with the systems. The modifications must link the BASIC programs and the procedures into one continuous FIT or WPV.

Section 4
Configuring Your 7411B

INTRODUCTION

This section provides information that will you help you configure your 7411B operating code to complement the system that you use. The five major topics discussed in this section are:

- Decision Factors
- Configuring Operating Code
- Translating a Procedure or Result Disk
- Editing a Procedure to Run on Your System
- Adding a Printer to Your System

There are two main decision factors. They involve the criteria for configuring a system for your workload and choosing the software for the system. Both factors are considered under the Decision Factors subheading.

Operating Code is not configured on a day to day basis. Instead it is configured when the system is installed. Thereafter it need only be changed when an instrument in the system is changed. Configured operating code will run when a selected instrument is physically missing from the system. The section on configuring

operating code includes a step-by-step description on how to use the 7411B Configuration Utility and Instrument Library disks to automatedly configure your operating code.

You may have procedures that run on pre-7411A Fluke 7400 or A123 series systems or procedures that run on a 7411A system. In the case of pre-7411A procedures you need first to translate the procedures that run on pre-7411A systems to 7411A type procedures. The section on translating procedures includes a step-by-step description on how to use the 7411B translation and utility disk to automatically translate your procedures.

Procedures written on pre-7411A Fluke 7400 or A123 series systems that use the CON or RUNE Function Selection Codes must be edited to run under the control of the 7411A. Procedures that use the ASK or RUN Function Selection Codes may need to be edited to run under the control of the 7411A.

See pages 4-47 and 4-48 of this manual and the descriptions of the CON, RUNE, ASK+, ASK-, and RUN Function Selection Codes in the Procedure Writing Manual for more information.

A procedure disk for the 7411A system needs to be translated as an 7411B procedure disk by creating the Directory Structure File on a the Disk and new procedure files that can be accessed through the Directory Structure. The contents of the procedures are not at all affected. Result files also need the addition of a directory structure to be compatible with the 7411B. A routine for conversion is added to the 7411B translation and utility disk.

A procedure that has been written on another system may need to be edited to run on your system. The section on

editing a procedure provides information that will help you edit a procedure via the Procedure Generator Editor capabilities of the 7411B.

There are a great many inexpensive RS-232-C compatible printers available today. You can select and supply one of these and include it in the system you configure. In most instances, the printer can be set to operate with the 7411B by changing some switches in the printer and connecting it to the 1722A's RS-232-C port with a null modem cable. Special 7411B files (the STRTUP.CMD and COMMND.INT files) can also be designed to match your printers capabilities. The section on adding a printer provides the information you need to modify this file.

DECISION FACTORS

NOTE:

The 7411B contains all Fluke Computer-Aided Calibration software developed to date. However, due to Fluke's ongoing program of hardware and software development, other options or accessories may become available. Contact your local Fluke representative for the latest information.

To configure the 7411B for your system, you should consider the following questions.

- What types of instruments will be calibrated?
- What is the required accuracy for each type?
- What is the volume of the workload for each type?
- Do you currently own Fluke instruments or systems?
- What is the skill level of the system operator(s)?
- Who will write and edit procedures?
- Is there a need to write additional BASIC drivers?
- Who will manage the system?

Answering the previous questions will help you decide:

- Whether to use your existing equipment in an upgrade program or obtain an entirely new system.
- What instruments to use in your system.

- How to partition your system.
- Which 7411B FSCs to use.
- Whether to combine or separate PGE and INT.
- If you need to use the 5200A-800 software.
- If you will use the Cal History Management software.
- How to use the Fluke Certified and User's Group instrument calibration procedures.
- How to use the Functional Integration Test (FIT) and Performance Verification (PV) procedures.
- How much memory to install in the 1722A.
- Whether to install one or two IEEE-488 and RS-232 ports in your 1722A controller.

CHOOSING A SYSTEM FOR YOUR WORKLOAD

New Installations

Figure 4-1 illustrates the most common configurations of the newer 7411B-based calibration systems and their applications. Refer to the corresponding data sheets for performance specifications of these instruments and systems.

These systems can be set up for new users or configured for upgrading an existing system by adding the 7411B and necessary hardware. The 7404B Data Sheet provides information for upgrading kits. Contact your local Fluke sales office for information regarding other upgrades.

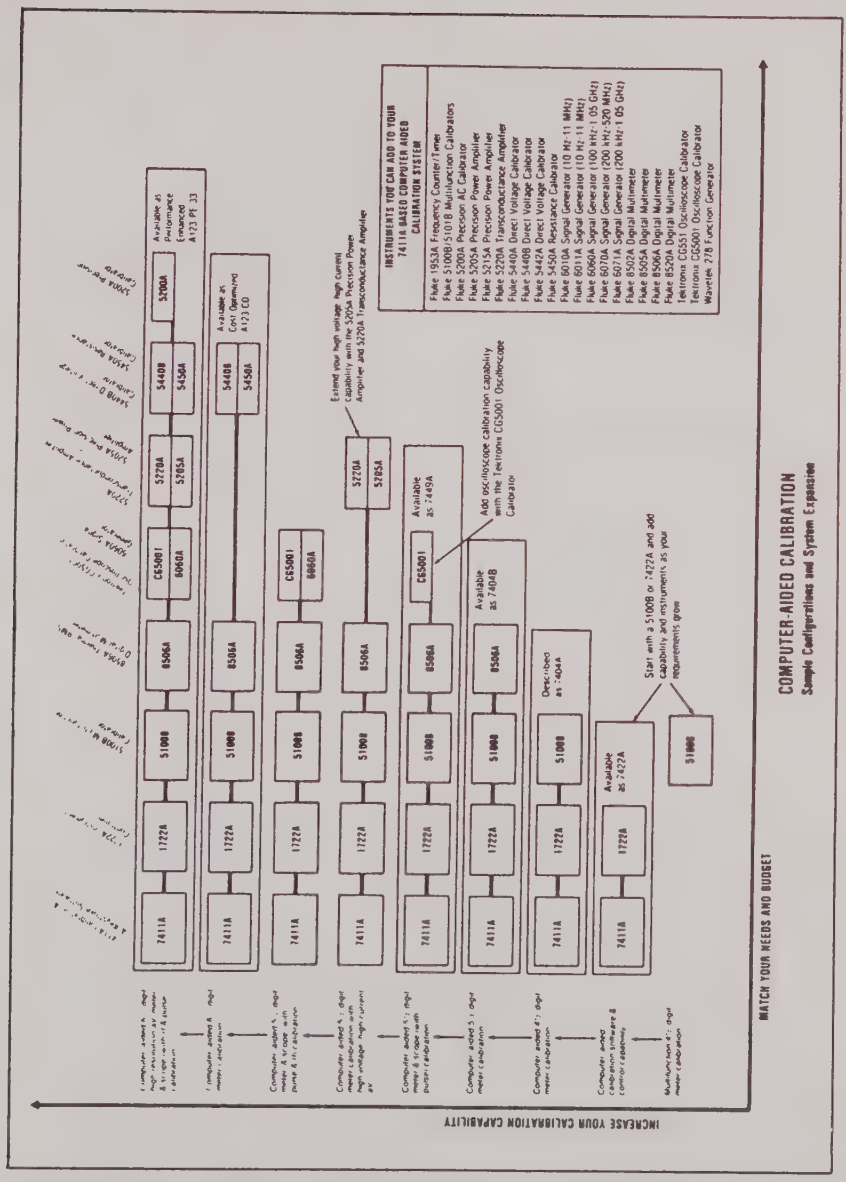

COMPUTER-AIDED CALIBRATION
Sample Configurations and System Expansion
INCREASE YOUR CALIBRATION CAPABILITY
MATCH YOUR NEEDS AND BUDGET
INSTRUMENTS YOU CAN ADD TO YOUR 7411B BASED COMPUTER AIDED CALIBRATION SYSTEM
Fluke 1953A Frequency Counter/Timer
Fluke 5100B/5101B Multifunction Calibrators
Fluke 5200A Precision AC Calibrator
Fluke 5205A Precision Power Amplifier
Fluke 5215A Precision Power Amplifier
Fluke 5220A Transconductance Amplifier
Fluke 5440A Direct Voltage Calibrator
Fluke 5440B Direct Voltage Calibrator
Fluke 5442A Direct Voltage Calibrator
Fluke 5450A Resistance Calibrator
Fluke 6010A Signal Generator (10 Hz-11 MHz)
Fluke 6011A Signal Generator (10 Hz-11 MHz)
Fluke 6060A Signal Generator (100 kHz-1 05 GHz)
Fluke 6070A Signal Generator (200 kHz-520 MHz)
Fluke 6071A Signal Generator (200 kHz-1 05 GHz)
Fluke 8502A Digital Multimeter
Fluke 8505A Digital Multimeter
Fluke 8506A Digital Multimeter
Fluke 8520A Digital Multimeter
Tektronix CG5351 Oscilloscope Calibrator
Tektronix CG5001 Oscilloscope Calibrator
Wavetek 278 Function Generator
Available as Performance Enhanced A123 PR 33
Available as Cost Reducing A123 CO
Available as 7405A
Available as 7404B
Described as 7404A
Available as 7422A
Extend your high voltage, high current capability with the 5205A Precision Power Amplifier and 5220A Transconductance Amplifier
Add oscilloscope calibration capability with the Tektronix CG5001 Oscilloscope Calibrator
Start with a 5100B or 7422A and add capability and instruments as your requirements grow
7411A
1722A
51000
8506A
CG5001
6060A
5220A
5205A
5440B
5450A
5700A

Figure 4-1. Sample Configurations and System Expansion

The A123 configurations provide high performance, including accuracy and configuration, to address high volume workloads. The 7404B and 7449A provide economical approaches to handling these workloads.

Some environments demand oscilloscope/meter calibration capability. The 7449A or A123-PE-33 provide this capability. Other environments dictate a parallel flow of workload through separate systems for meter and oscilloscope calibration. An A123 and 7449A, or an A123 and 7410A can be used to provide this capability.

The 7411B combines with any of the instruments compatible with the IEEE-488 bus as shown in Figure 4-1.

NOTE:

Some earlier versions of the A123 included an electronic load and 6-range ac/dc transconductance amplifier. These devices were indirectly programmed over the IEEE-488 bus via a Fluke 2205A switch matrix and custom-fabricated analog and digital programming cables. Because of these custom-designed cables, the electronic load and transconductance amplifier are not tabulated on the inset but are available in the 7411B Instrument Library disk as the 2500 and DLVP. The use of these FSCs is described in the 7411B Procedure Writing Manual.

If you want to configure your own rack-mounted version of a 7411B-based calibration system, you should read Sections 2 through 5 of the Fluke System Builder's Guide. These sections also contain information to guide you in configuring a general purpose dc and low frequency analog test system that uses the 7411B.

Upgrading Existing Systems

Fluke Models 7404A Meter Calibration Cluster, 7409A Oscilloscope Calibration Cluster, 7405A Meter Calibration Workstation, and 7410A Oscilloscope Calibration Workstation can be upgraded to operate in a 7411B environment. A Fluke 1722A Instrument Controller is needed to run the 7411B software. If you are using the 1720A Instrument Controller, you can upgrade your system to include 7411B capability by adding a Fluke 7422A/TR.

When a 7404A or 7409A are upgraded to use the 7411B, they can be used in any of the configurations shown in Figures 1-1 through 1-5. The 7405A and 7410A are not in the direct expansion path shown in Figure 4-1, but the 7411B adds capabilities to these instruments while running them. For example, you can configure a combined 7405A/7410A that is controlled by one 1722A or add a high accuracy calibration cluster outside of the 7405A to upgrade its calibration to 6 1/2 and 7 1/2-digit DMMs.

CHOOSING THE SOFTWARE FOR YOUR SYSTEM

PGE and INT Operating Code

The 7411B includes a Configuration Utility and Instrument Library disk. These are used to configure separate or combined versions of PGE and INT. A combined version of PGE and INT is very useful during procedure development because the same procedure is kept in memory during the editing and testing phases of the development process. Separate versions of PGE and INT are useful when you are restricting the number of people who have access to editing the procedures.

When PGE and INT are resident on separate disks, it is possible to load both of them into the 1722A E-Disk, and to run them both on the 1722A as though they were

supplied on a single disk. To take advantage of this feature, the 1722A must contain 1 megabyte of memory when there are four or more instruments in the system.

A step-by-step description of how to configure PGE and INT is located further on in this section under the heading, Operating Code.

Calibration History Management Software

The Cal History Management software is used to manipulate calibration history data to create user-defined reports. Typical reports might generate calibration recall lists or track instrument inventories. Calibration History Management software is described in Section 7 of the 7411B Operator Manual.

5200A-800 Software

The 5200A-800 software is used to characterize a Fluke 5200A to improve its 90-day accuracy specification, and allows the 5200A to calibrate ac voltage ranges of a Fluke 8506A DMM within seven hours of characterization. The characterization program of a 5200A-800 runs on a stand-alone basis to create a data file in the 1722A E-Disk. The 1722A File Utility program should be used to transfer this data file, called 5200.DAT, from the 1722A E-Disk to the 7411B Calibration Software Disk 1 or 2 for floppy disk system, or to WD0 for a hard disk system. Then the file is automatically loaded into the 1722A E-Disk at the 1722A boot (start or restart) from the Calibration Software Disk. Refer to the 1722A System Guide, Section 4, for information on File Utility program.

7411B PROCEDURES

General Information

If you have older 7400-series procedures that are not

included in a 7411A environment, you can translate them to the 7411A environment via a Translator disk provided for this purpose. The translation only changes the following information in the procedures header.

- SYSTEM TYPE is changed from 7405A to 7411A.
- CALIBRATION ID is changed from a binary number to a roster of the instruments that are required to execute the procedure.

NOTE:

The 7411B software is designed to run programs in any system because there are no software checks for determining if a system contains the same Function Select Codes (FSCs) or instrumentation as in the original 7411B system program. You should look at the header of the Fluke Certified and User's Group procedures to determine whether or not your system contains the required instruments and FSCs.

After translating the 7411A format and storing the procedures on a procedure disk, you must create a new procedure disk with the directory structure on it. The 7411B Translation and Utilities Disk contains the program to create this new disk automatically.

A step-by-step description of how to translate a procedure is located further on in this section under the heading, Translating Procedures.

Fluke Example Procedures

Fluke Example procedures are provided by Fluke as examples for procedure writing.

Carefully inspect your equipment to ensure that the IEEE-bus interface of your 1722A Instrument Controller and calibration instruments is free of defects, the IEEE-488 cables are properly connected to the controller and calibration instruments, and the IEEE-488 bus address switches of the instruments are the same as those used in the procedure. Also check to see that the calibration instruments are within their calibration performance specifications.

You must decide whether these procedures conform to your calibration needs, the messages displayed on the 1722A's CRT are appropriate for the system, the sequence of calibration events are set up for your application, and the test accuracy ratios between the system and the Unit Under Test (UUT) or Test Instrument (TI) conform to the system's internal standards.

If the procedures do not meet your needs, you can edit any of the procedures to conform to your needs via the 7411B PGE program.

User's Group Procedures

User's Group procedures are available to help reduce initial investment in software development. These procedures can be used as they are or edited.

FIT and WPV

Functional Integration Tests (FIT) are provided for some workstations and clusters. FITs determine the functionality of instrumentation systems. FITs do not test all functions and ranges of the instruments in the system. However, they do provide useful information, in such instances as a major failure in an instrument.

Some A123 systems provide Workstation Performance Verification tests (WPV). The WPVs test the performance

of some of the calibration instruments in a system against the external standards that are traceable to NBS. You can refer to the listing extracts of some of these under the "Software" tab divider in this binder and use them as guides for developing a performance verification test for your cluster or workstation.

OPERATING CODE

Overview

Because the 7411B can be used in a variety of different systems, you must configure the 7411B for your application. The configuration procedures listed in this section only need to be done once, unless you change your system. It typically takes 1/2 to 2 hours to configure a 7411B.

You configure the 7411B for the following:

- Standard 7405A, 7404B, 7449A, 7410A applications (with customized variations allowed).
- Combined Procedure Generator/Editor and Instrument Calibration disks (if allowed by the number of disk blocks used; see Step 8 further on in this section).
- Customized connection messages at the Test Interface Panel.
- IEEE-488 addresses for the system instruments that are different than the Fluke default addresses.
- Customized locations for the softkeys of the Function Selection Code (FSC) keypad used in procedure generation
- System Type and Scope/Meter Station characteristics. These characteristics override the Fluke default characteristics while maintaining the other characteristics you choose.
- Customized headers for Procedures, Results, UUT Code and selection of slew step increments of 1/10% or 10/100% of tolerance.

To configure your 7411B, you need the following materials, which are supplied in the 7411B software package:

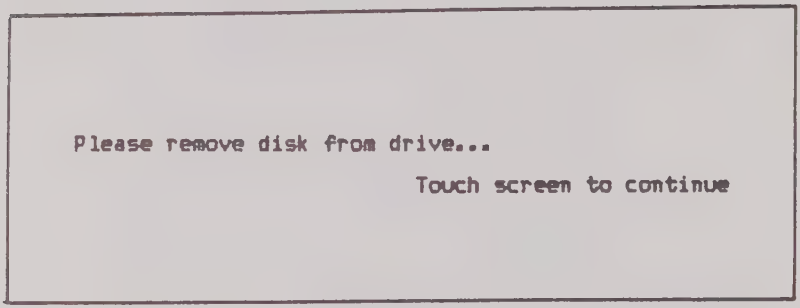
- 7411B Configuration Utility disk.
- 7411B Instrument Library disk.
- 7411B Calibration Software Disk 1.
- 7411B Calibration Software Disk 2.
- Labels for each Calibration Software disk.
- 7411B Translation and Utility disk if converting procedures from existing pre-7411B calibration software.

Step-by-Step Description

The following steps describe in detail how to configure your 7411B system.

First, insert the Configuration Utility disk in the 1722A, and press RESTART.

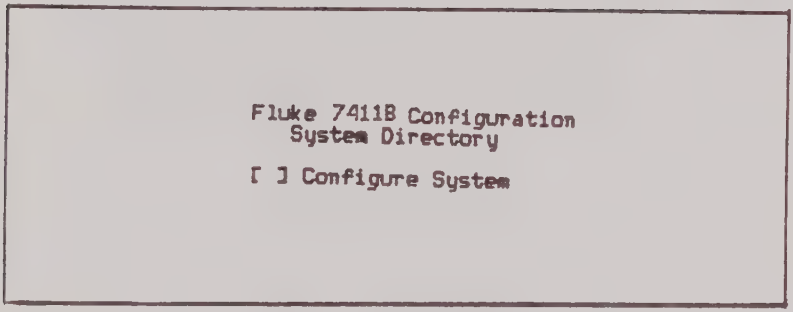
The 1722A screen updates to:



Remove the disk and touch the screen.

Step 1

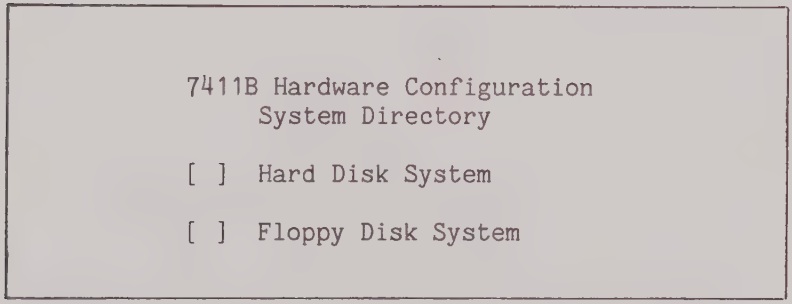
The 1722A screen updates to:



Press: [x] Configure System

Step 2

The 1722A screen updates to:

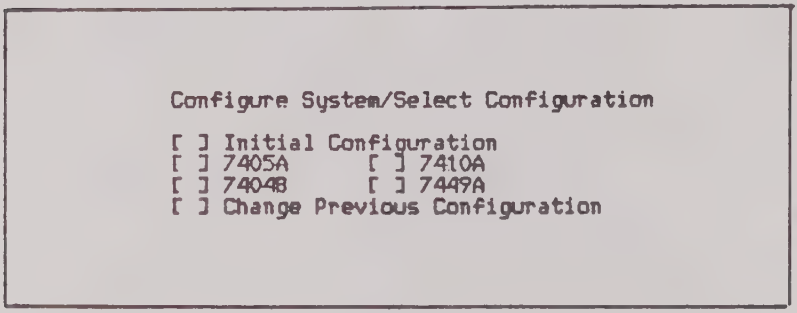


Select [X] Hard Disk System to configure the calibration system to use the 1765B Winchester Disk as the storage device for programs, procedures and results.

Select [X] Floppy Disk System to use the built in floppy disk drive of the the 1722A to start up programs, enter procedures, and to store results on floppy disk.

Step 3

The 1722A screen updates to:



[X] Initial Configuration is selected when configuring a custom designed system. The system will be notified of through this configuration procedure of the presence in the system of any instrument for which a driver (or Function Selection Code, see the Procedure's Writing Manual for more information) exists. The next step is Step 4.

[X] 7405A , [X] 7410A , [X] 7404B , or [X] 7449A is selected to notify the calibration system of the standard instrument configuration associated with the model number of the system.

If this option is selected, the next menu is Step 6.

[X] Change Previous Configuration is selected when changing an existing system configuration. You will be prompted:

Since the previous configuration has not yet been loaded, you have to indicate whether the previous system configuration is on floppy or hard disk:

```
Source Existing 7411B Configuration Information:

[ ]  Hard Disk

[ ]  Floppy Disk
```

If selecting [X] Hard disk, the existing configuration information will be read from the Winchester disk; if selecting [ ] Floppy Disk, another prompt will appear:

```
Insert 7411B Calibration Software Disk 1

                              ADV  RESELECT
```

The current configuration is read from the Calibration Software Disk 1. The next screen is as in Step 4. If you only want to make changes in the messages, headers, slew rate factor, select DONE in step 4 to reach the first Configuration Edit menu; continue with Step 26 to make those changes not affecting instrument configuration in the calibration system.

Step 4

The screen updates to:

```
Select Instruments in Configuration

1953   Universal Counter-Timer
NEXT LAST  SELECT  DESELECT              DONE
```

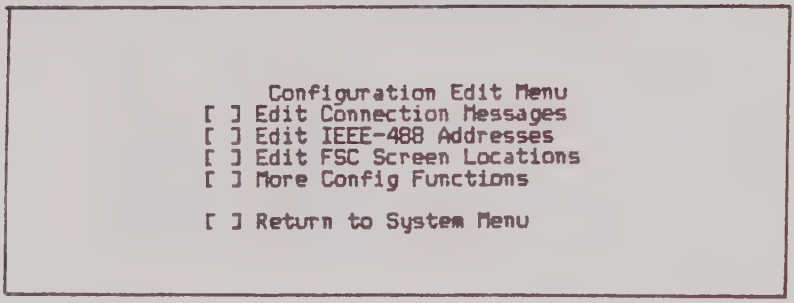
If a 1953 is in your system, press SELECT. If there is no 1953, press NEXT, until the model number of an instrument in your system is displayed, then select it. You can back up in this menu by pressing LAST, and you can change your mind by pressing DESELECT. The message, Selected, flashes above each instrument you select.

The following steps assume that a 1953, 5001, 5100, 7405TIP, and 7410ATIP are selected.

When you have finished selecting the instruments in your system, press DONE.

Step 5

The screen updates to:


Configuration Edit Menu
[ ] Edit Connection Messages
[ ] Edit IEEE-488 Addresses
[ ] Edit FSC Screen Locations
[ ] More Config Functions
[ ] Return to System Menu

Press: [x] Return to System Menu

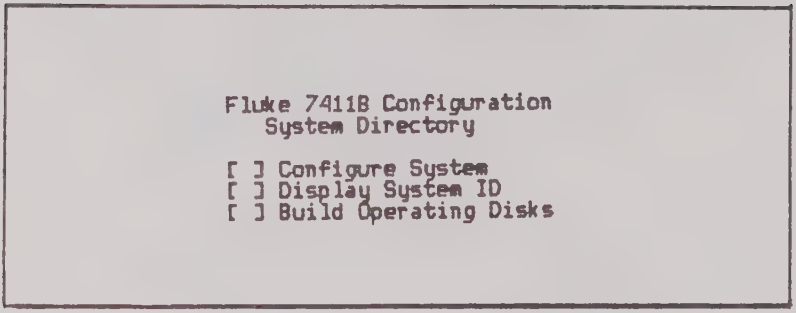
This menu is the first of 3 Configuration Edit Menus that deal with other items besides the presence of instruments in the system. The second Configuration Edit Menu is obtained by selecting [X] More Config Functions. The third Configuration Edit Menu is reached from the second Configuration Edit Menu by selecting again [X] More Config Functions. If you select [X] More Config Functions in the third Configuration Edit Menu, you will loop back to the first Configuration Edit Menu.

If you select:

[X] Edit Connection Messages, the next step is Step 27.
[X] Edit IEEE-488 Addresses, the next step is Step 29.
[X] Edit FSC Screen Locations, the next step is Step 31.
[X] More Config Functions, the next step is Step 35.
[X] Return to System Menu, the next step is Step 6.

Step 6

The screen updates to:



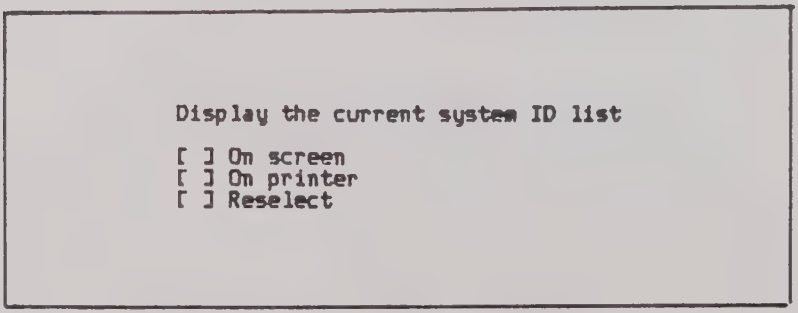
Press: [x] Display System ID

NOTE

The selection [] Exit Configuration Utility is displayed in the Configuration System Directory after steps 1-16 have been completed.

Step 7

The screen updates to:



Press: [x] On screen

Step 8

If "INITIAL CONFIGURATION" was selected in Step 3 and the FSCs of step 4 were selected, the screen updates to:

```
System ID:
      1953  5001  5100  7405TIP  7410TIP

System Type:  7411A  Meter Calibration
Combined Procedure Generator/Editor and
     Instrument Calibration Disk blocks      =  823
Procedure Generator/Editor only Disk blocks =  464
Instrument Calibration only Disk blocks     =  523
```

System ID: is the roster of your instrument FSCs
System Type: 'Meter Calibration' means ASK- D is enabled
'Oscilloscope Cal..' means ASK+ D is enabled

The number of blocks determines whether you can build a combined Procedure Generator/Editor (PGE) and Instrument Calibration (INT) disk for a floppy-disk based system, as is described in Step 10.

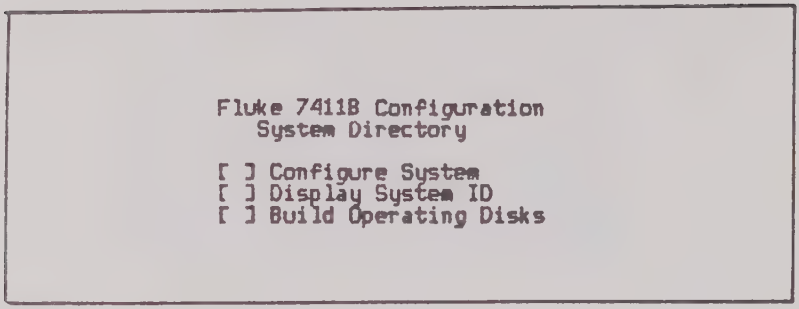
A floppy disk can store 798 blocks of data, but a combined PGE/INT disk for the configuration above requires 823 blocks. A combined PGE/INT disk cannot be built for this configuration, so separate disks must be used for PGE and INT, containing the number of data blocks indicated.

However, if a 7404B was selected in Step 3, a combined PGE/INT can be built according to the information given in Step 10.

Press: ADV

Step 9

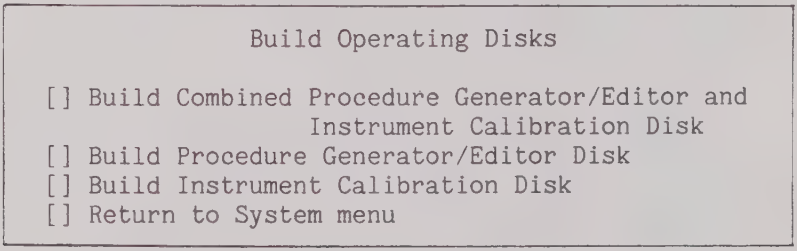
The screen updates to:



Press: [x] Build Operating Disks

Step 10

If the system is being configured as Floppy Disk based, the screen updates to:


Build Operating Disks
[] Build Combined Procedure Generator/Editor and
Instrument Calibration Disk
[] Build Procedure Generator/Editor Disk
[] Build Instrument Calibration Disk
[] Return to System menu

The selection

[] Build combined Procedure Generator/Editor and Instrument Calibration Disk

does not appear if more than 798 disk blocks are needed. Refer to Step 8, above.

NOTE

The description of how to build a combined PGE/INT is not given here. However, the process is similar to the description for building separate PGE/INT.

If the system is to be Hard Disk based, the screen updates to:

```
Build Operating Disks

[] Build Combined Procedure Generator/Editor and
                Instrument Calibration Disk
[] Return to System menu
```

The menus in the following steps are not shown since they are unnecessary: Steps 12 and 14 (Insert 7411B Calibration Software Disk 1); Step 15 (Please apply the following label ....); Steps 18 and 20 (Insert 7411B Calibration Software Disk 1); Step 21 (Please apply the following label ....)

NOTE

Steps 1-6 need to be completed before the Exit Configuration option will be available. Press:

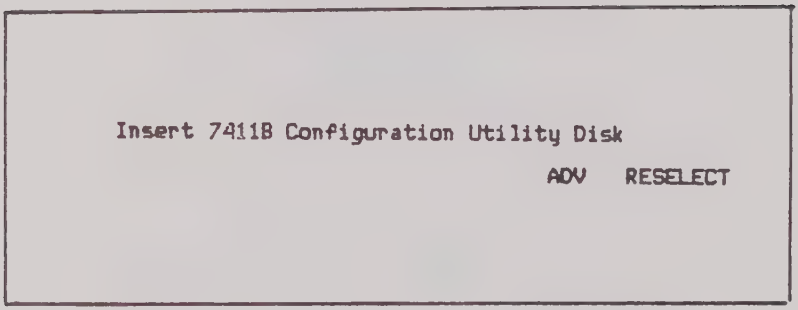
[] Build Procedure Generator/Editor (floppy system)

or

[] Build combined Procedure Generator/Editor and Instrument Calibration Disk

Step 11

The screen updates to:



Insert the Configuration Utility disk into the 1722A and press ADV.

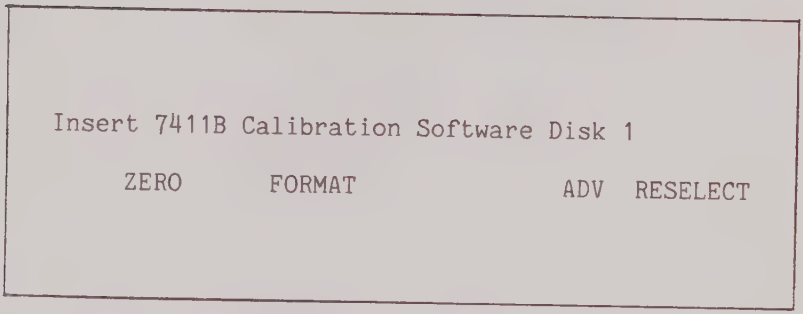
The screen displays: Copying Files, Please Wait

Step 12

NOTE:

Step 12 is not displayed if the system is configured as a hard disk based system.

The screen updates to:



Insert the disk and press FORMAT.

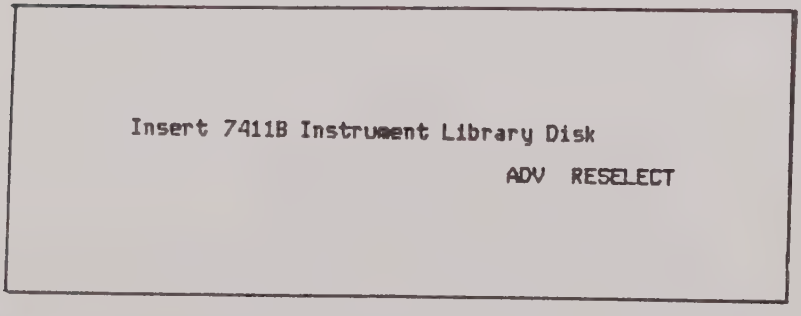
NOTE:

Press ZERO if you are using a formatted disk that contains data you no longer wish to keep.

The screen displays: Formatting Disk, Please Wait
The screen displays: Copying Files, Please Wait

Step 13

The screen updates to:



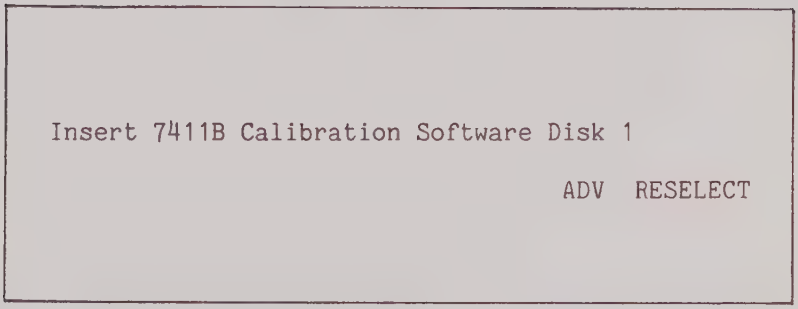
Insert the disk and press ADV.

The screen displays:

Copying Files, Please Wait

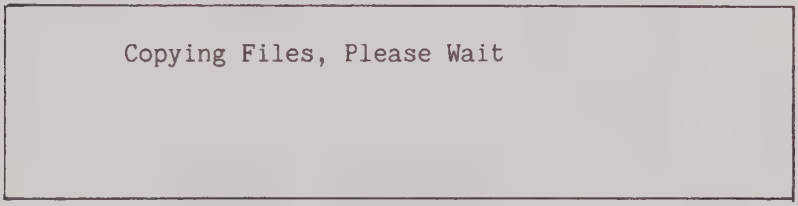
Step 14

The screen updates to:



Insert the disk and press ADV.

The screen displays:



Step 15

NOTE:

Step 15 is not displayed if the system is configured as a hard disk based system.

The screen updates to:

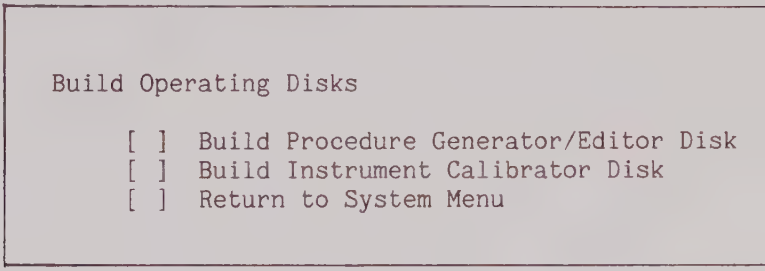
```
Please apply the following label to this Calibration
Software Disk 1


     Procedure Generator/Editor
                                        ADV
```

Remove the disk, locate the Procedure Generator/Editor label, and put it on the disk. Then press ADV.

Step 16

The screen updates to:



If you select:

[X] Build Procedure Generator/Editor Disk:

You will return to Step 11 (this would only be desirable if something appeared to go wrong during the previous steps.

[X] Build Instrument Calibration Disk:

Continue with Step 17.

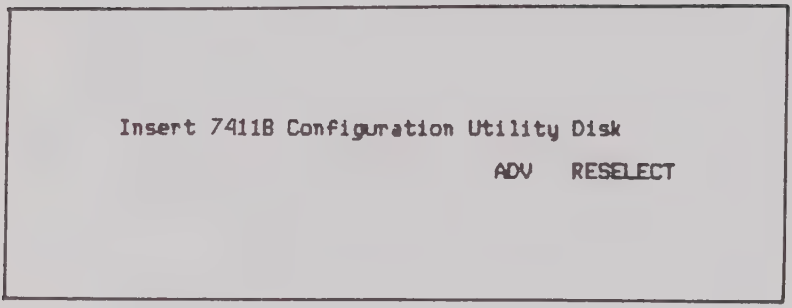
[X] Return to System Menu:

This brings you to Step 9.

Press: [X] Build Instrument Calibration Disk.

Step 17

The screen updates to:



Insert the disk and press ADV.

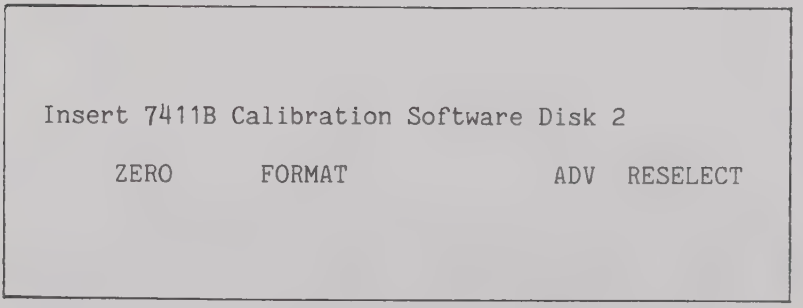
The screen displays: Copying Files, Please Wait

Step 18

NOTE:

Step 18 is not displayed if the system is configured as a hard disk system.

The screen updates to:



Insert the disk and press FORMAT.

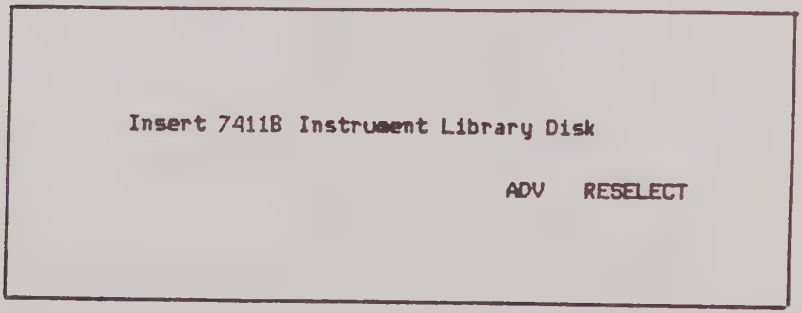
NOTE:

Press ZERO if you are using a formatted disk that contains data you no longer wish to keep.

The screen displays: Formatting Disk, Please Wait
The screen displays: Copying Files, Please Wait

Step 19

The screen updates to:



Insert the disk and press ADV.

The screen displays: Copying Files, Please Wait

Step 20

NOTE:

Step 20 is not displayed if the system is configured as a hard disk system.

The screen updates to:

```
Insert 7411B Calibration Software Disk 2

                                    ADV  RESELECT
```

Insert the disk and press ADV.

The screen displays: Copying Files, Please Wait

Step 21

NOTE:

Step 21 is not displayed if the system is configured as a hard disk system.

The screen updates to:

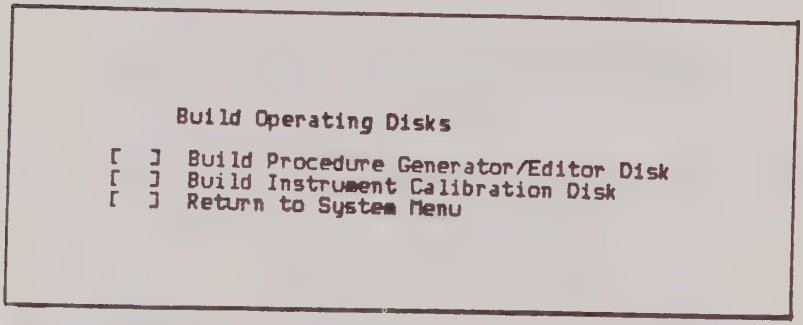
```
Please apply the following label to this
Calibration at a Keystroke Software Disk
      Instrument Calibration

                                    ADV
```

Remove the disk from the 1722A, locate the Instrument Calibration label, and apply the label to the disk. Then press ADV.

Step 22

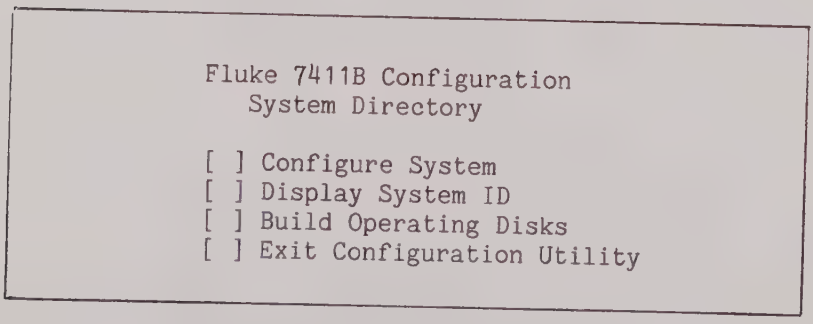
The screen updates to:


Build Operating Disks
[ ] Build Procedure Generator/Editor Disk
[ ] Build Instrument Calibration Disk
[ ] Return to System Menu

Press: [x] Return to System Menu

Step 23

The screen updates to:


Fluke 7411B Configuration
System Directory
[ ] Configure System
[ ] Display System ID
[ ] Build Operating Disks
[ ] Exit Configuration Utility

If selecting:

[X] Configure System:

This option is used if you want to change any of the settings made earlier, attach the Y1700 keyboard to the 1722A and continue with Step 24. In Step 24 select DONE to reach the first Configuration Edit Menu.

[X] Display System ID:

The next step is Step 8.

[X] Build Operating Disks:

Guides you back to Step 10.

[X] Exit Configuration Utility:

This will terminate Configuration program, show the operator to press RESTART and ABORT on the front panel of the 1722A at the same time, to start loading of the configured calibration software. In case of a Floppy Disk based system, the PGE (Disk 1) should be inserted in the floppy disk drive of the 1722A. In the case of a hard disk based system, no floppy disk should be present in the floppy drive.

NOTE

The menu selection

[] Exit Configuration Utility

will not appear until a "complete" system has been successfully built, either as a combined PGE/INT or both a PGE and INT disk.

If you do not want to change the following:

- Connection messages
- IEEE-488 Addresses
- FSC Screen Locations
- System Type
- ASK+/ASK- for scope/meter stations
- Headers for Procedures and Results
- UUT Code text
- Slew Rate Factor

from their default settings, you have finished configuring the 7411B and you select [X] Exit Configuration Utility.

However, if you want to change any of the settings mentioned above, attach the Y1700 keyboard to the 1722A and press: [X] Configure System.

Step 24

The screen updates to:

```
Source Existing 7411B Configuration Information from:

     [] Hard Disk
     [] Floppy Disk
```

After making this selection, the screen updates to:

```
Configure System/Select Configuration

[] Initial Configuration
[] 7405A        [] 7410A
[] 7404B        [] 7449A
[] Change Previous Configuration
```

In order to reach the Configuration Edit menus, you have to select [X] Change Previous Configuration and press DONE when prompted to change instrument selection.

Press: [X] Change Previous Configuration

Step 25

The screen updates to:

```
Select Instruments in Configuration

Selected

1953   Universal Counter-Timer
NEXT  LAST  SELECT  DESELECT     DONE
```

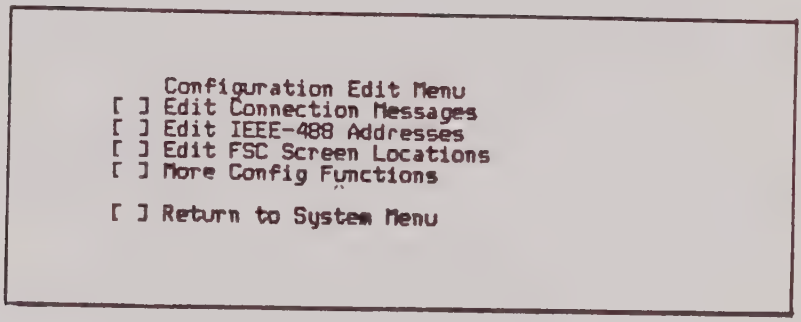
NOTE

The word "Selected" only flashes for instruments in the configuration.

Press DONE (you have already selected the instruments in Step 4).

Step 26

The screen updates to:


Configuration Edit Menu
[ ] Edit Connection Messages
[ ] Edit IEEE-488 Addresses
[ ] Edit FSC Screen Locations
[ ] More Config Functions
[ ] Return to System Menu

There are three Configuration Edit Menus to change default settings, headers and the slew rate factor in the 7411B system. This step shows the first of three Configuration Edit menus.

The second Configuration Edit Menu is reached by selecting [X] More Config Functions; the next menu is in Step 35. First discussed is the first option in the first Configuration Edit Menu.

The option [X] Edit IEEE-488 Addresses starts Step 29, the option [X] Edit FSC Screen Location starts Step 31.

An automatic connection message appears on the screen at calibration time. In customized workstations, this message may not conform to the Test Interface Panel nomenclature. Additionally, the specific instruments used in your system may be driven by a generic FSC, for example Fluke Models 8500A, 8502A, and 8505A DMMs are all driven by the 8500 FSC, and all use the automatic connection message, 8505A Input.

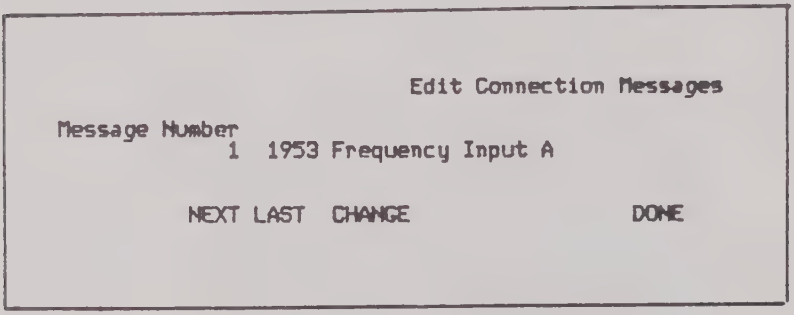
These automatic connection messages can be changed by the Edit Connection Message utility to conform to your customized needs.

An example of an automatic connection message is, 5100B Output, shown in the sample screen in the figure titled, Standard Connection Message, in Section 5 of the 7411B Operator Manual.

Press: [x] Edit Connection Messages.

Step 27

The screen updates to:



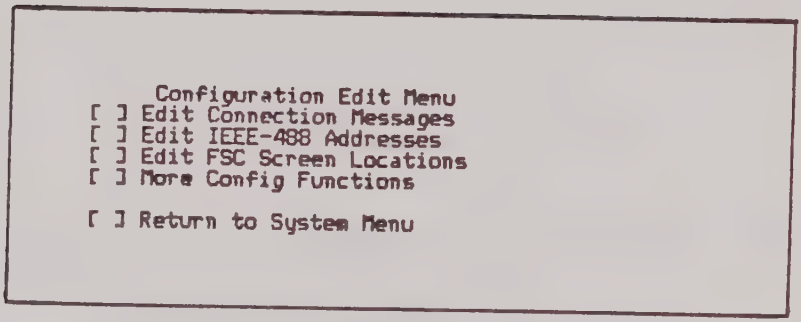
If you do not wish to change the message that is displayed, press NEXT.

To change the message, press CHANGE. The screen then prompts you to change the message from the keyboard. Enter the new message, followed by a carriage return <CR>.

Press NEXT (or LAST to back up) until you have changed all of the messages you wish to customize. Then press DONE.

Step 28

The screen updates to:

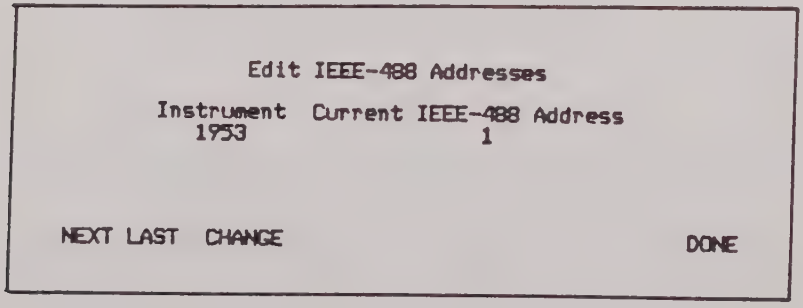

Configuration Edit Menu
[ ] Edit Connection Messages
[ ] Edit IEEE-488 Addresses
[ ] Edit FSC Screen Locations
[ ] More Config Functions
[ ] Return to System Menu

If you want the IEEE-488 addresses for the instruments in your system to be different from the 7411B default addresses (e.g. if you want to use both "FlexSys" ATLAS and 7411B software in your system and you want the 7411B addresses to conform to the "FlexSys" ATLAS addresses), then

Press: [x] Edit IEEE-488 Addresses

Step 29

The screen updates to:



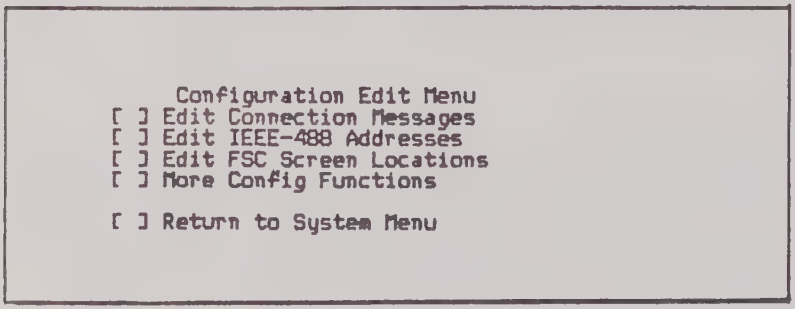
Press CHANGE to change the address using the Y7000 keyboard.

The screen updates to prompt you to change the address. Respond to the prompt by entering the new address and a <CR>.

Press DONE to exit the editing sequence.

Step 30

The screen updates to:


Configuration Edit Menu
[ ] Edit Connection Messages
[ ] Edit IEEE-488 Addresses
[ ] Edit FSC Screen Locations
[ ] More Config Functions
[ ] Return to System Menu

If you wish to reorganize the pattern of FSC softkeys used during procedure generation or editing (see the figure titled, FSC Selection During Insert Display, in Section 3 of the 7411B Procedure Writing Manual for the 7404B default softkey pad), then

Press: [x] Edit FSC Screen Locations

Step 31

The screen updates to display the FSCs in the default pattern and prompts you by displaying the following:

Select F.S.C. to be moved.

Touch the FSC you want to move.

Step 32

Note that the selected FSC blinks, the DONE softkey disappears, and the screen prompts you by displaying the following:

Select location to move F.S.C. to.

Touch the location where you want to place the FSC.

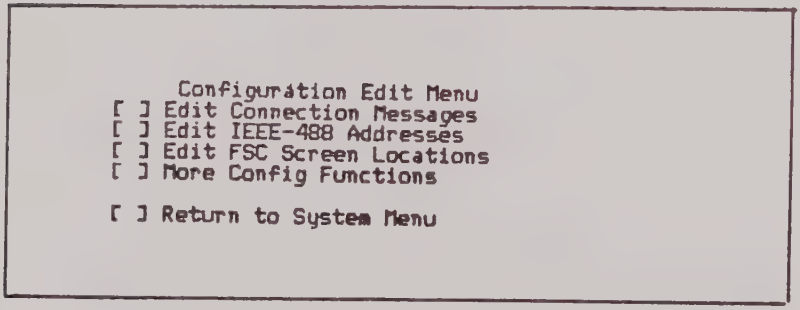
Step 33

Note that the FSC moves to the chosen location and the DONE softkey reappears.

When you are finished moving FSCs, press DONE.

Step 34

The screen updates to:


Configuration Edit Menu
[ ] Edit Connection Messages
[ ] Edit IEEE-488 Addresses
[ ] Edit FSC Screen Locations
[ ] More Config Functions
[ ] Return to System Menu

To change the system type or change the scope/meter station type, press:

[x] More Config Functions

Step 35

The screen updates to:

```
        Configuration Edit Menu

[ ]  Edit System Type
[ ]  Select Scope/Meter Station
[ ]  Select Slew Rate Factor
[ ]  More Config Functions

[ ]  Return to System Menu
```

Step 35 is the second Configuration Edit Menu, providing means to change:

System Type (the next step is 36),
Scope or Meter station (the next step is 37) or
Slew Rate Factor (the next step is 38).

If [X] More Config Functions is selected, the third Configuration Edit Menu is reached: continue with Step 39.

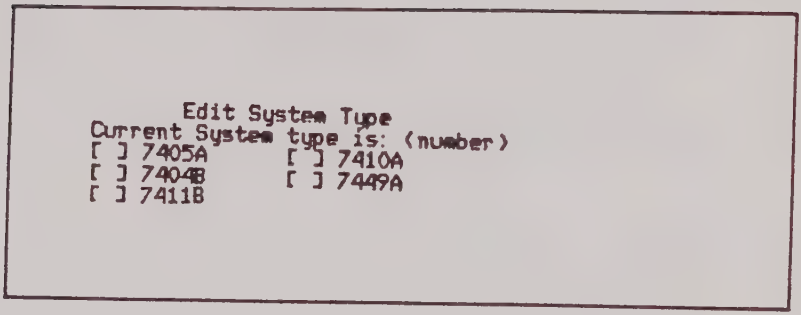
Selecting [X] Return to System Menu returns control to the menu in Step 9.

To change the system type, for example to treat a 7411B as a 7404B, press:

[x] Edit System Type

Step 36

The screen updates to:



Select the new system type (e.g. 7404B).

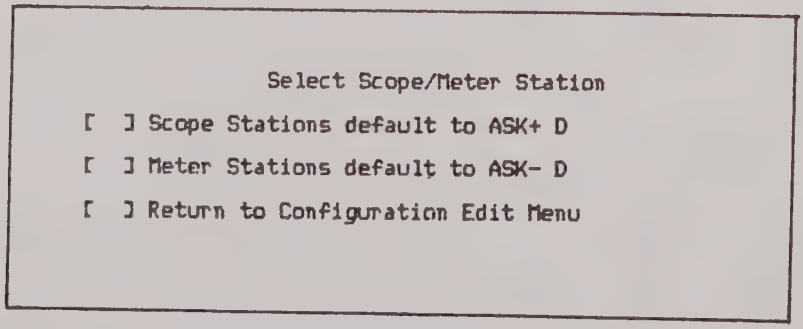
NOTE:

If you return to the main menu to get the System ID, the instrument FSCs you have previously selected remain the same, but only the System Type: is changed (e.g. from a 7411B to a 7404B).

After you have selected the System Type, you will return to the menu shown in Step 35.

Step 37

The screen updates to:


Select Scope/Meter Station
[ ] Scope Stations default to ASK+ D
[ ] Meter Stations default to ASK- D
[ ] Return to Configuration Edit Menu

If you press: [x] Scope Stations default to ASK+ D and then return to the main Fluke 7411B Configuration System Directory to display the System ID, the System Type: is now configured for scope calibration (or meter calibration if you selected, Meter Stations default to ASK- D).

After making a selection, control returns to the menu shown in Step 35.

Step 38

In order to adjust the value of the calibration system so that the UUT reads the nominal value, four display keys are shown on the screen of the 1722A: L/\ , S/\ , L\/ and S\/. Selecting the softkeys with L causes a large percentage in the change of output value and selecting a softkey with S causes a change 1/10 of the step size of the L softkeys. The minimum L softkey step is 10% of the tolerance as in the tolerance field; therefore the minimum value of a step change by selecting S is 1% of the tolerance specified.

The slew rate factor multiplies these step changes. The default value is 1. The default value in the 7411A and pre-7411A system is 10 (the step changes were 100% and 10% of tolerance). Unlike in the 7411A system, where the slew rate factor was fixed, this factor can be selected at configuration time.

After selecting Change Slew Rate Factor in Step 35, the screen updates to:

```
Select a Slew Rate Factor

Current Slew Rate Factor is 1

CHANGE                                DONE
```

If you press [CHANGE], you will be prompted for the new value:

```
Select a Slew Rate Factor

Current Slew Rate Factor is 1

Enter new value (1-20): __
```

If you do not enter a factor between 1 and 20, an error message will be displayed:

```
Slew Rate Factor entered is not between 1 and 20!!
```

After completing the entry for a new value, you will return to the previous menu.

If you select [DONE], you will return to the Configuration Edit menu (step 35).

Step 39

The third Configuration Edit menu is reached by selecting [X] More Config Functions in the second Configuration Edit Menu shown in Step 35:

```
Configuration Edit Menu

[ ]  Edit Procedure Header
[ ]  Edit UUT Identifier Field
[ ]  Edit Results Header
[ ]  More Config Functions

[ ]  Return to Configuration Menu
```

If selecting:

[X] Edit Procedure Header

You can change the title on the first line on procedure listings as desired. The length of the input string will be truncated to 55 characters. The default string is: JOHN FLUKE MFG. CO., INC. The next step is 40.

[X] Edit UUT Identifier Field

You can change the default identifier "UUT CODE:" in the header of the results listing to any text desired. The string will be truncated to 20 characters. The next step is 41.

[X] Edit Results Header

You can change the title on the first line on result listings as desired. The length of the input string will be truncated to 55 characters. The default string is: JOHN FLUKE MFG. CO., INC. The next step is 42.

[X] More Config Functions

Returns control to the first Configuration Edit Menu as shown in Step 26.

[X] Return to System Menu

Returns control to the menu shown in Step 9.

Step 40

After selecting Edit Procedure Header, the screen updates to:

```
Current Procedure Header is:

     JOHN FLUKE MFG. CO., INC.

Do you wish to change it?

YES                              NO
```

If you respond with NO, you return to step 39.

If you respond with YES, a keyboard is displayed on the screen. After completing the entry, you will return to step 39.

Step 41

After selecting Edit UUT Identifier Field, the screen updates to:

```
Current UUT Identifier Field is
      UUT Code

Do You Want to Change It?

YES                              NO
```

If you respond with NO, you return to Step 39.

If you respond with YES, a keyboard is displayed on the screen. After completing the entry, you will return to step 39.

Step 42

After selecting Edit Results Header, the screen updates to:

```
Current Result Header is:

 JOHN FLUKE MFG. CO., INC.

Do you wish to change it?

YES                                NO
```

If you respond with NO, you return to step 39.

If you respond with YES, a keyboard is displayed on the screen. After completing the entry, you will return to step 39.

TRANSLATING A PROCEDURE

Introduction

This section describes translating existing procedures into the 7411B system. The 7411B system allows you to call procedures directly to speed up the selection of a desired procedure from the system disk (which can be the floppy disk or the Winchester Disk.

In the 7411B system a procedure is called by the entry in the first INSTRUMENT field in the header of the procedure. A user has 51 characters to identify a procedure that way and therefore can be rather descriptive. Unfortunately, the 1722A can handle only file names with 6 characters in the base name and 3 characters extension, not enough to create meaningful file names, an operator could easily recognize. Therefore a Directory Structure is used which operates pretty much as a telephone book:

The 7411B system after being instructed to look for a procedure with a long (up to 51 characters) name, accesses a file that contains the directory, finds the short name behind the long name and accesses the procedure, which in reality is stored on the disk medium under the short file name.

These names are of the form $nnnn$.PRO, where nnnn can be 1 through 9999. In theory, there could be 10,000 possible file names, but in reality the directory structure limits the number of procedure files to 1023 on Hard Disk and 48 on each floppy.

Results disks can also be quickly accessed through another directory structure. The virtual name used consists of:

UUt/Property Code;
Calibration date;
Calibration time;
R (for a complete Result file) or S (for a Summary result file);
Name of procedure used, so that the total name is truncated to 51 characters.

Result files are stored under real file names "rslt.xx", where xx is 1 through 99. The maximum number of result files on the system is 99.

The conversion utility reads a 7411A Procedure Disk or Results Disk in its entirety. After being prompted to do so, it reads the first entry in the Instrument field in the header of each procedure (for a Procedure Disk or the content of the header of each Results Disk), makes an appropriate entry in the Directory file and selects a short file name under which the procedure or result is actually stored and then stores the procedure in that file. This continues until all procedures or results are written back.

Translation of 7411A Disks to 7411B Disk

To translate a Procedure or Results Disk, first format a new disk.

1. Insert the Translation and Utility Disk and press the RESTART button on the front panel of the 1722A controller. The following prompt will appear.

```
TRANSLATION AND UTILITY DISK

[] 7411A Procedure/Result
[] Pre-7411A Procedures to 7411A
[] Reformat hard Disk

[] Return to FDOS
```

Press [x] Return to FDOS

If you already have a newly formatted disk, skip steps 2 through 5.

2. Type fup.

3. Insert the disk to be formatted.

4. Type /f and respond YES when asked if you really want to format the disk you just inserted into the Floppy Disk drive.

NOTE:

In case of a Procedure Disk, if there are any BASIC routines that are called by any of the procedures (using RUN or RUNE), they should be copied also. It is convenient to copy those procedures now while in FUP. Refer to steps shown after the description of translating the main procedures.

5. After the disk has been formatted, which takes a few minutes, type /x to return to the FDOS prompt. Remove the newly formatted disk from the floppy disk drive.

To continue translating a procedure disk do the following:

6. Type MENU.

   The Translation and Utility Menu will appear. Press

   [x] 7411A Procedure/Results Conversion

   The screen of the 1722A will now prompt you with the message:

   Insert Old Procedure or Results Disk Without Directory And Touch the Screen when Done

7. Insert the Procedure/Results Disk without directory in the Floppy Disk Drive and touch the screen. A prompt will appear while the procedure/results are copied into E-disk of the 1722A:

   Copying Old Procedure File Into Memory

8. After all procedure/results on the Procedure/Result Disk without Directory have been copied, a new prompt will appear:

   Insert A New Blank Procedure/Result Disk And Touch Screen When Done

   Insert a newly formatted floppy disk and touch the screen. A new message will appear:

   Copy Procedure/Results Onto New Disk

9. After all procedure/results have been copied on the new disk with the Directory, the Translation & Utility Menu will re-appear. Press

   [x] Return to FDOS

   Remove the disk from the floppy disk drive.

Copying BASIC Routines

The BASIC routines that are called through the use of the RUN and RUNE FSC must be separately copied. To copy those routines, after selecting FDOS, type FUP. Then:

1. Insert the Master floppy disk with the BASIC routines to be copied.

2. Copy the BASIC routines from the Master Floppy disk into E-disk by typing:

   ```
   fup>ed0:=mf0:*.bas
   ```

3. Remove the Master floppy disk from the disk drive and insert the 7411B compatible floppy disk.

4. Copy the BASIC routines from E-disk back onto the new disk by typing:

   ```
   fup>mf0:=ed0:*.bas
   ```

5. Remove the BASIC routines from E-disk by typing:

```
fup>ed0:*.bas/d
```

NOTE:

In a hard disk based system, BASIC subroutines must be stored on WD0:.

6. Return to FDOS with:

```
fup>\x
```

TRANSLATING A PROCEDURE FROM PRE-7411A TO 7411A

This section describes translating existing procedures into the 7411A system. After translating into the 7411A format you will need to convert it to the 7411B format by running the 7411A to 7411B conversion routines.

To translate procedures to the 7411A format, first format a new disk and make a backup copy of your procedures. Be sure to store the master copy in a safe place in case your copy gets damaged. Second, copy the 7411A software onto the newly copied procedures disk. Follow the steps below to perform this translation.

To make a backup copy of a new disk:

1. To boot up, turn on the 1722A system and Insert the 1722 System Software Disk. The following information will come up on the screen.

```
Total system memory - 648 Kbytes
E-Disk - 544 Kbytes, free - 0 Kbytes (0 blocks)
FDOS>
```

The number of bytes of total system memory will vary depending upon the system.

NOTE:

If the BASIC program appears on the screen first, type: exit <return>

2. An FDOS> prompt immediately appears. Respond by typing:

   fup <return>

   The screen will display the following information:

```
FDOS> fup
File Utililty Program Version 1.5

FUP>
```

3. Remove the 1722A system disk and insert the disk to be formatted for a backup of your procedures.

4. You are again prompted by FUP>. To respond, type:

   mf0:/f <return>

   The screen shows the following:

```
FUP>
mf0:/f
Really format MF0:?
```

5. Answer the question on the screen by typing:

   yes <return>

This tells the system that you want to format the new disk. When the system is finished formatting the disk (approximately 1-2 minutes), again the FUP> prompt appears:

```
FUP>
```

6. Respond to this prompt by typing:

```
ed0:/z
```

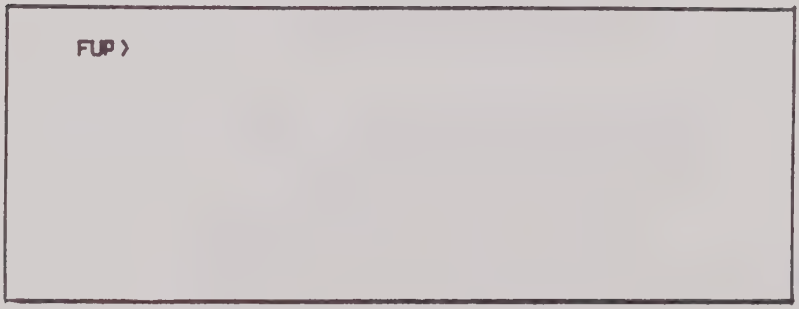
The above command tells the system to zero the RAM disk directory in the 1722A in order to store the contents of your procedures disk. As displayed on the screen the system asks you to verify that you want to empty the directory.

```
FUP> ed0:/z
Really zero ED0:?
```

7. Answer by typing:

    yes <return>

    to verify that you want to execute this command. Now the screen prompts you with:



8. Remove your newly formatted disk and insert the original procedures disk.

    Respond to the FUP> prompt by typing:

    ed0:=mf0:/w

As the system copies the original procedure files, the screen will display information similar to the following:

```
Copying  MF0:PROCED.1
Copying  MF0:PROCED.18
Copying  MF0:PROCED.2
Copying  MF0:PROCED.28
Copying  MF0:PROCED.3
Copying  MF0:PROCED.38
Copying  MF0:PROCED.4
Copying  MF0:PROCED.48
Copying  MF0:PROCED.BAS

FUP>
```

9. Take the procedures disk out and insert the new procedures disk that you removed in step 8.

10. Copy the procedure from RAM (ED0:) onto this new disk by typing after the FUP> prompt:

    ```
    mf0:=ed0:/w
    ```

    RAM already contains the contents of your original procedures disk. The above command tells the system to copy RAM onto the new disk.

A screen similar to the following will appear.

```
Copying  EDO:PROCED.1
Copying  EDO:PROCED.1B
Copying  EDO:PROCED.2
Copying  EDO:PROCED.2B
Copying  EDO:PROCED.3
Copying  EDO:PROCED.3B
Copying  EDO:PROCED.4
Copying  EDO:PROCED.4B

FUP>
```

11. Ignore the FUP> prompt, remove the Procedures disk, insert the 7411B Translation & Utilities Disk and push the 'RESTART' key on the 1722A. The following menu will appear on the screen:

```
        TRANSLATION AND UTILITY DISK

[] 7411A Procedure/Results
[] Pre-7411A Procedures to 7411A
[] Reformat Hard Disk

[] Return to FDOS
```

Press [x] Pre-7411A Procedure to 7411A Conversion.

Now the following message will appear on the screen:

```
LOADING
7411A Translator Software

Wait until the system prompts you with the
following message:
```

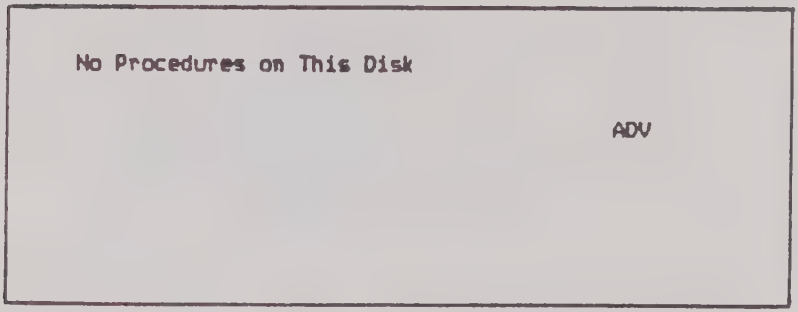
12. Remove the disk and press ADV. You will see the prompt below.

```
Fluke Calibration System Directory:
[ ] Start Procedure Translation
```

13. Insert the new procedures disk (removed in step 11) to be translated, and press the brackets on the touch screen to select start Procedure Translation:

    [X] Start Procedure Translation

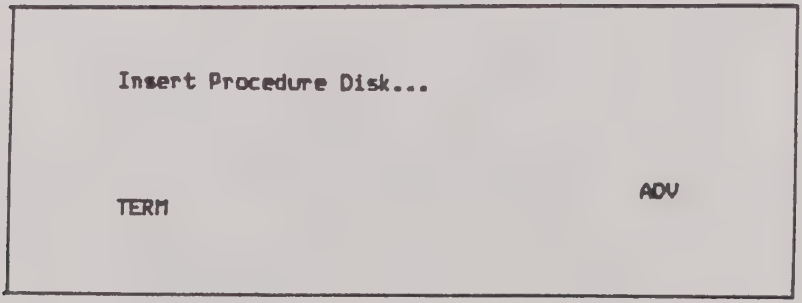
Normally, the screen displayed in step 15 will appear. However, if there are no valid procedures, the screen will display the following message:



14. Press:

    ADV

The system tells you to:



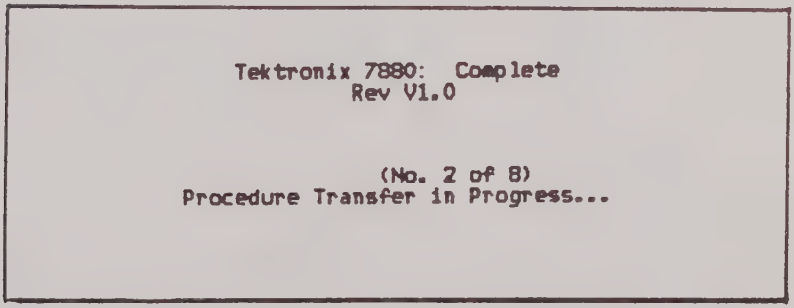
Insert a disk with procedures on it and press:

ADV

15. A screen similar to the sample screen below will display the:

    - o name of the instrument
    - o revision
    - o the number of the procedure and its position on the disk, and
    - o the translation status

    The translation status alternates between Procedure in Progress and File Being Updated. During this time the disk light may flash on and off. The translation takes approximately one minute for each procedure.



When translation is complete, the display shown in step 14 will reappear.

Your procedures have been translated into the 7411A system compatible format. Now they need to be translated into 7411B format. Refer to the section called Translating 7411A Procedures and Results Disk to 7411B Procedures and Results.

We suggest that you first backup your library of untranslated procedures disks and run all of them through the translation procedure.

NOTE:

The 7411A as well as the 7411B software displays the roster of instruments in the procedure header necessary to run a procedure. Carefully check the list. The instruments listed must be the ones used or the program will not run. If you are using instruments not listed, you must modify the procedures.

To return to instrument calibration, procedure generation, etc., insert the applicable disk (in case of a floppy disk system) and press RESTART.

EDITING A PROCEDURE TO RUN ON YOUR SYSTEM

Why a Translated Procedure May Need Editing

The 7411A Translation Utility doesn't check to see whether or not the Functions Selection Codes (FSCs) used in a procedure supplied by another user can be run in your system. In addition, the Control Data array for the 7411A is different than the Control Data array used in an 74xxx or A123 system that you are upgrading to use the 7411A. Therefore you may need to edit a translated procedure to run on your system if:

1. The instruments in your system are different than the instruments required by a procedure that was not written specifically for your system.

2. A RUNE Function Selection Code is used in the procedure, regardless of whether the procedure was written specifically for your system or another one. (See the following description and the RUNE Function Selection Code description in the Procedure Writing Manual.)

3. The CON Function Selection Code is used in the procedure. (Refer to CON Function Selection Code description in the Procedure Writing Manual.)

4. The 7411B is configured to calibrate meters and oscilloscopes.(Refer to the ASK+ and ASK- Function Selection Code description in the Procedure Writing Manual.)

5. The RUN Function Select Code is used in the procedure and it uses the Control Data Array (CONT.INT).

Editing for Different Instruments

If your system contains instruments with stimulus/measurement capabilities that are similar to the instruments used in the procedure being edited, simply substitute the FSC for the instrument in your system for the one called out in the procedure. Note that the substitute FSC may or may not be completely compatible with the original one. For example the 5440 FSC can directly replace all of the accuracies and levels provided by the 5100 FSC but the reverse isn't true because a 510xB isn't as accurate as a 544xx.

Information on how to change (replace) a FSC is provided in the Procedure Writing Manual, page 3-10.

RUNE

If you have a procedure that incorporates the RUNE FSC, the BASIC program that it calls must begin as follows:

```
CLOSALL\OPEN 'CONTRL.INT' AS OLD DIM FILE 1%
DIM#1,CO(83),C1%(73),C2$(42),C3$(89)=64,C4%(274),CD%(32,5),CL$(17)=
CL$(17)=32
```

NOTE:

This line must be changed for all procedures that were not written with the 7411A. See the description of the RUNE function selection code in the procedure writing manual for more information.

ADDING A PRINTER OR BAR CODE READER TO YOUR SYSTEM

PORT CONNECTIONS OF PRINTER AND BAR CODE READER TO THE 1722A

The printer to be added to the 7411B calibration system must be connected to Port 0 (KB1:) and any bar code reader must be connected to Port 1 (KB2:), which is on the optional IEEE-488 interface.

NOTE

The Port (KB2:) serial interface can also be used for REMOTE transfer of files between the 1722A and an external host computer.

Serial Port Characteristics

The characteristics of KB1: and KB2: serial interfaces are determined by 2 files named STRTUP.CMD and COMMND.INT. An explanation on the content of these files and how to change them for different characteristics follows later in this section. These files are located on both Calibration Software Disk 1 and Calibration Software Disk 2 or on WD0: (in case of a Hard Disk based system).

o	Baud Rate	4800	
o	Data Bits	8	
o	Parity	none	
o	Stop Bits	1	
o	End of Line	10	(ASCII character 10, decimal)
o	End of File	26	(ASCII character 26, decimal)
o	Stall Input	off	
o	Stall Output	off	
o	Time Out	0	(for KB1:); 30 (for KB2:)

Printer Information

Almost any RS-232-C compatible printer can be used with the 7411B. Default characteristics as described under Serial Port Characteristics are used. If necessary, they can be modified as described under Modifying STRTUP.CMD and COMMND.INT files for changing Serial Port Characteristics.

BAR CODE READER INFORMATION

Bar Code Reader Equipment

Which types of bar codes can be read by the system is determined by the capability of the bar code reader itself. There are many different types of bar code readers commercially available. Some types can read only one particular bar code and others can automatically sense and read differences of bar codes. From the point of view of the 7411B system, what is important is that the data must be sent from the bar code reader to the 1722A over the RS-232-C interface. The default characteristics are the same as those for the printer, except the Time Out is set to 30 seconds (to accomodate transfer of files to host computers, if also used for that purpose).

In order to implement bar code reading capability you need to do the following:

- Obtain a bar code reader (decoder plus input device)
- Obtain a suitable null modem interconnect cable.
- Reconfigure the bar code reader to match the characteristics of 1722A serial Port 1 (KB2:)

Recommendation for Bar Code instrumentation:

The following bar code reader is recommended for use with the 7411B Calibration system:

INTERMEC* Model 9510 On-Line Wand Reader
(Autodiscriminating decoder, capable of reading CODE 39, HIBC, Interleaved 2 of 5, 2 of 5, Codabar, UPC, EAN, and CODE 11).

INTERMEC Part Number 9510B0101
INTERMEC Part Number 9510B0102

(Applications requiring VDE approval)

You should also order:

INTERMEC Part Number 046854, 9510 Systems Manual

The following input device is recommended for use with the 9510 Reader:

INTERMEC Model 1260 High Resolution Visible Light Digital Wand,

Part Number 1260A0101

One of the following power packs is required for DC supply of bar code reader and wand; order the appropriate Part Number for your line voltage and frequency:

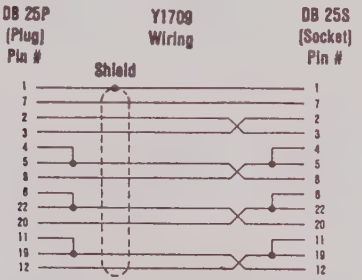
Line Voltage	Line Frequency	INTERMEC Part Number
120V ac	60Hz	046791
120V ac	50 Hz	046971
100V ac	50/60 Hz	046972
220V ac	50/60 Hz	046973
240V ac	50/60 Hz	046974

* INTERMEC is a registered trademark of INTERMEC Corporation

Information on price and availability of INTERMEC products can be obtained from INTERMEC representatives worldwide. Contact: INTERMEC Corporation, PO Box 360602, Lynnwood, WA, 98046-9702, USA Telephone (206) 348-2600.

Connecting the Bar Code Reader to the 1722A

To connect the bar code reader with Port 1 (KB2:) of the 1722A an RS-232-C Null Modem Cable, such as the Fluke Y1709, is required. A schematic of this cable is shown below.



Setting up the INTERMEC 9510 Bar Code Reader

Connect the wand and the power pack to the decoder. Plug the power pack into a suitable line receptacle.

Connect the Fluke Y1709 cable from the Modem Port on the 9510 to Port KB2: on the 1722A. Turn the 9510 on.

The 9510 needs to be configured. The default setup values need to be modified by wanding the appropriate bar code symbols in the INTERMEC 9510 System Manual, Section 4, under "Configuring the Reader". At least the following has to be done to make the Bar Code Reader configuration compatible with the characteristics of the Serial Port 1 (KB2:) of the 1722A as defined in the unmodified STRTUP.CMD and COMMND.INT files.

Locate the table for Point-to-Point Parameters and select:

4800 Baud,
Disabled Parity,
8 Data Bits, and
1 Stop Bit.

The new configuration will not be lost when power is removed from the bar code reader.

In addition, it will be possible to disable bar codes which you will not be using; refer to the 9510 System Manual, Section 4 under the heading "Configuring the Reader" for more information.

An Explanation of the STRTUP.CMD File

The file "STRTUP.CMD" on the Instrument Calibration Disk is similar to this: (the line numbers are not in the file)

```
1  TIME
2  &\e[2J\e[6;37H\e[5mLOADING\e[0m
3  &\e[08;24H\e[1m7411B Calibration Software V1.00\e[15;0H
4  SET
5  KB1: br 4800 db 8 pb n sb 1 eof 26 eol 10 si e so e to 0
6  KB2: br 4800 db 8 pb n sb 1 eof 26 eol 10 si e so e to 30
7  ex
8  FUP
9  ED0:/C-1
10  y
11  ed0:/z2
12  y
13  ed0:=/w
14  ed0:/a
15  STRTUP.CMD/d
16  STRTUP.CMD=COMMND.INT/r
17  /p
18  /x
19  system
```

Line 1 invokes the Time and Date Utility program to request the user to set the time and date of the internal time clock if the status shows that the clock has lost power since the last time it was set.

Lines 2-3 display the 'LOADING' message and the version number of the Calibration Software.

Line 4 starts up the Set Utility Program (SET)

Line 5 initializes the serial port KB1: (port 0) for the printer. The fields are described in the 1722A System Guide (p/n 716621) section on Serial Communications (the Set Utility Program). The fields and their descriptions are as follows:

KB1:	identifies the port
br 4800	baud rate is 4800 baud
db 8	8 data bits
pb n	no parity
sb 1	1 stop bit
eof 26	the End of File character is 26 (Ctrl-Z)
eol 10	the End of Line character is 10 (Line Feed)
si e	stall input is enabled
so e	stall output is enabled
to 0	timeout is 0

Line 6 initializes the serial port KB2: (port 1) for remote or the bar code reader.

Line 7 exits the SET program.

Lines 8 through 14 enter the File Utility Program, configure the E-Disk (EDO:), copy all files from the boot device (either the floppy disk or the hard disk) to the E-Disk (EDO:):, and assign EDO: as the system device.

Line 16 renames the file "COMMND.INT" as the new "STRTUP.CMD". This is the STRTUP.CMD what will be used

when RESTART is pressed on the 1722A front panel and the 1722A reboots from the E-Disk. (The "COMMND.INT" file is described under "AN EXPLANATION OF THE COMMND.INT FILE".)

Lines 17-18 pack the E-disk and exit the File Utility Program.

Line 19 invokes the main system program of the 7411B Calibration Software package.

An Explanation of the "COMMND.INT" File

The file "COMMND.INT" on the Instrument Calibration Disk is renamed to be "STRTUP.CMD" during the initial boot process. This is the STRTUP.CMD what will be used when restart is pressed on the 1722A front panel and the 1722A reboots from the E-Disk. The file is similar to this: (the line numbers are not in the file).

```
1  SET
2  KB1: br 4800 db 8 pb n sb 1 eof 26 eol 10 si e so e to 0
3  KB2: br 4800 db 8 pb n sb 1 eof 26 eol 10 si e so e to 30
4  ex
5  SYSTEM
```

Line 1 starts up the Set Utility Program (SET).

Line 2 initializes the serial port KB1: (port 0) for the printer. The fields are described in the 1722A System Guide (p/n 716621) section on Serial Communications (the Set Utility Program). The fields and their descriptions should be identical to those in line 5 of the "STRTUP.CMD" file on the boot device (MF0: or WD0:)

Line 3 initializes the serial port KB2: (port 1) for remote or the bar code reader.

NOTE

Lines 2-3 should be identical to Lines 5-6 of the "STRTUP.CMD" file on the boot device (MF0: or WD0:)

Line 4 exits the SET program.

Line 5 invokes the main system program of the 7411B Calibration Software package.

Modifying STRTUP.CMD & COMMND.INT Files for Serial Ports

If the characteristics of the RS-232-C interface of the printer or barcode cannot be modified, you need to change the appropriate contents of STRTUP.CMD and COMMND.INT files.

1. Read the information supplied with your printer and/or bar code concerning their RS-232C capabilities.

2. If the printer and/or bar code reader can be set per the default, you should plug the printer into KB1: and the bar code reader into KB2: and use them without further effort.

3. If the printer and/or bar code reader cannot be set as above, do the following:

   a. Read Section 4, Devices and Files, of the 1722A System Guide, which is supplied with the 1722A. Especially note the following information:

      - KB1: and KB2: under the heading, Devices, in Section 4.

- Command Files, the Startup Command File, and Other Command Files under the heading, Files, in Section 4.

- The File Utility program under the heading, The File Utility Program, in Section 4.

b. Read Section 5, Communications, of the 1722A System Guide, which is supplied with the 1722A. Especially note the information about Serial Communications in this section.

c. Read Section 6, Creating and Editing Programs, of the 1722A System Guide, which is supplied with the 1722A. Especially note the following information:

- File Utility Program.

- Command Line Interpreter.

- The Edit Program.

d. Read Section 7, Automating System Functions, of the 1722A System Guide, which is supplied with the 1722A. Especially note the information about Command Files and The Startup Command File found in this section.

Use the information under the heading, Information Resources, in this section as you do the following:

1. Place the 1722A System Software disk into the 1722A, and press RESTART. After entering the date and time, remove the disk from the 1722A when the following message is displayed:

```
Welcome to Fluke 1722A BASIC!

Ready
```

2. Exit from BASIC to FDOS, then go to the File Utility program.

3. Insert the 7411B Software Disk 1 and copy the file, STRTUP.CMD, from the disk into the 1722A, under the file name, STRTUP.NEW. After the FUP> prompt, enter the following:

```
EDO:STRTUP.NEW=MFO:STRTUP.CMD
```

   then press RETURN.

4. Remove the 7411B Software Disk 1 and reinsert the 1722A System Software disk.

5. Exit from FUP to FDOS and enter, EDIT STRTUP.NEW, followed by a carriage return.

6. Edit the Set portion of the STRTUP.NEW file to conform to your printer requirements, save the edited file as STRTUP.NEW, and exit from EDIT to FDOS.

7. Remove the 1722A System Software disk.

8. With a floppy disk system, remove the write protect tab from the 7411B Software Disk 1 and insert the disk in the 1722A.

9. Enter the File Utility program and (with a floppy disk system) copy the edited command file from the 1722A memory to the 7411B disk by entering the following command:

```
MFO:STRTUP.CMD=EDO:STRTUP.NEW
```

   then press RETURN.

With a Hard Disk:

```
WD0:STRTUP.CMD=ED0:STRTUP.NEW
```

and skip steps 10 and 11.

10. Replace the write protect tab on the 7411B Software Disk 1.

11. Repeat steps 8 through 10 for the 7411B Software Disk 2.

12. Repaeat steps 3 through 12 for the COMMND.INT file.

INITIALIZING A HARD DISK FOR YOUR 7411B SYSTEM

Introduction

This section describes the initialization of the Winchester Disk for your 7411B system. This procedure should only be executed if for some reason your hard disk crashed. This procedure is not necessary after purchasing a hard disk, since it is initialized at the factory. If this procedure is used, all information on the hard disk is definitively wiped out, therefore this capability of the 7411B system has been made a separate utility to prevent accidental erasures.

You should keep a copy of all programs, procedures and the bar code file, if used, on floppy disks. Furthermore, you should make backup copies with regular intervals to prevent the loss of results. Fluke recommends strongly to review backup procedures in detail to prevent substantial loss of information in case a crash of the Winchester Disk does occur.

Initialization

In order to initialize the hard disk, perform the following steps:

CAUTION:

EXECUTION ERASES ALL INFORMATION ON THE HARD DISK.

1. Insert the 7411B Translation and Utility Disk in the Floppy Disk drive and Press the Restart button on the front panel of the 1722A Controller.

The Controller will now display the Translation and Utilities Menu:

```
        TRANSLATION & UTILITIES MENU

[] 7411A Procedure/Results Conversion
[] Pre-7411A Procedures to 7411A Conversion
[] Reformat Hard Disk
[] Return to FDOS
```

Press [x] Reformat Hard Disk.

The 1722A will now display the following warning message:

```
WARNING THIS PROGRAM WILL ERASE ALL DATA CURRENTLY ON HARD DISK
                DO YOU WISH TO CONTINUE?

          YES                          NO
```

If select NO, you will return to FDOS directly. If you select YES, initialization of the Hard Disk will commence.

Initialization will take up to 5 minutes.

During this time the message "Initializing the Hard Disk" will be displayed. After the initialization has been completed you will return to FDOS.

2. To restart the 7411B calibration program, type "system".

Appendix
Data Sheets

Specifications (90 days, 23°C±5°C)

Meter Calibration (7404B and 7449A)

Multifunction Direct Volts Specifications from 5100B

Range	Total Uncertainty, ±(ppm of output + floor)	Resolution	Load Current	Temperature Coefficient 0°C to 18°C, 28°C to 40°C
0-20 mV	38+5.2 μV	0.1 μV	See Note 1, 2	±(5 ppm output + 1 ppm range + 1 μV)/°C
20-200 mV	38+6.6 μV	1 μV	See Note 1, 2	±(5 ppm output + 1 ppm range + 1 μV)/°C
0.2-2V	38+21 μV	10 μV	See Note 1, 2	±(5 ppm output + 1 ppm range + 1 μV)/°C
2-20V	38+165 μV	100 μV	25 mA	±(5 ppm output + 1 ppm range + 1 μV)/°C
20-200V	38+1.6 mV	1 mV	10 mA	±(5 ppm output + 1 ppm range + 1 μV)/°C
200-1100V	38+16 mV	10 mV	6 mA	±(5 ppm output + 2 ppm range)/°C

Multifunction Direct Volts Specifications from 5100B enhanced by 8506A

Range	Total Uncertainty, ±(ppm of output + floor)	Resolution	Load Current	Temperature Coefficient 0°C to 18°C, 28°C to 40°C
0-20 mV	22+1.6 μV	0.1 μV	See Note 1, 2	±(5 ppm output + 1 ppm range + 1 μV)/°C
20-200 mV	22+1.6 μV	1 μV	See Note 1, 2	±(5 ppm output + 1 ppm range + 1 μV)/°C
0.2-2V	14+6.2 μV	10 μV	See Note 1, 2	±(5 ppm output + 1 ppm range + 1 μV)/°C
2-20V	10+160 μV	100 μV	25 mA	±(5 ppm output + 1 ppm range + 1 μV)/°C
20-128V	17+600 μV	1 mV	10 mA	±(5 ppm output + 1 ppm range + 1 μV)/°C
128-200V	17+6 mV	1 mV	10 mA	±(5 ppm output + 1 ppm range + 1 μV)/°C
200-1100V	17+6 mV	10 mV	6 mA	±(5 ppm output + 2 ppm range)/°C

[1] Source resistance of 50Ω on the 20 mV, 200 mV, and 2V ranges.
[2] 50Ω divider override available for low impedance meters.

Multifunction Alternating Volts Specifications from 5100B

Range	Total Uncertainty, ±(ppm output+floor)			Resolution	Load Current[4]	Temperature Coefficient 0°C to 18°C, 28°C to 40°C
	50 Hz to 1 kHz[3]	2 kHz to 10 kHz[3,6]	20 kHz to 50 kHz[3]			
1-20 mV[5]	500+51 μV	500+51 μV	800+52 μV	0.1 μV	See Note 6	
20-200 mV	500+60 μV	500+60 μV	800+66 μV	1 μV	See Note 6	
0.2-2V	500+150 μV	500+130 μV	800+210 μV	10 μV	See Note 6	
2-20V	500+1 mV	500+1 mV	800+1.65 mV	100 μV	25 mA	±(20 ppm output +
20-110V	500+10 mV	500+10 mV	800+16 mV[7]	1 mV	10 mA	2 ppm range)/°C
110-200V	500+10 mV			1 mV	10 mA	
200-1100V	500+55 mV			10 mV	6 mA	

Multifunction Alternating Volts Specifications from 5100B enhanced by 8506A

Range	Total Uncertainty, ±(ppm output+floor)			Resolution[8]	Load Current[4]	Temperature Coefficient 0°C to 18°C, 28°C to 40°C
	50 Hz to 1 kHz[3]	2 kHz to 20 kHz[3]	30 kHz to 50 kHz[3]			
12.5-125 mV[5]	300+7 μV	300+7 μV	650+10 μV	0.1 μV	See Note 6	±(20 ppm output+ 2 ppm range)/°C
125-200 mV	180+2 μV	180+2 μV	650+2 μV	0.1 μV	See Note 6	
0.2-2V	180+20 μV	180+20 μV	650+20 μV	1 μV	See Note 6	
2-20V	180+200 μV	180+200 μV	650+200 μV	10 μV	25 mA	
20-110V	180+2 mV	180+2 mV		100 μV	10 mA	
110-125V	180+2 mV			1.0 mV	10 mA	
125-200V	300+2 mV			1.0 mV	10 mA	
200-600V	300+10 mV			10 mV	6 mA	

[3] There are 28 discrete frequencies over the entire range.
[4] Maximum capacitive load of 875 pF to 20V and 275 pF from 20 to 1100V.
[5] For UUT bandwidth <1 MHz.
[6] Limited by 50Ω output resistance.
[7] Limited to 20 kHz.
[8] Stimulus resolution. Refer to "Measurement, Alternating Volts" specification in this data sheet for enhancement resolution.

External AC Divider Specifications driven by 5100B

Range 0.2 to 20 mV[9]	Total Uncertainty, ±(ppm of output+floor)		Resolution	Load Current	Temperature Coefficient 0°C to 18°C, 28°C to 40°C
	50 Hz to 10 kHz[1]	20 kHz to 50 kHz[3]			
5100 Only	1000+10 μV	1200+10 μV	0.1 μV	50Ω output	±(40 ppm of output+ 2 ppm range)/°C
Enhanced by 8506A[10]	800+5 μV	1200+5 μV	0.1 μV	impedance	

[9] For UUT bandwidth <10 MHz.
[10] External connections required.

Boost Power Amplifier Output Specifications from 5205A driven by 5100B: (optional)

Range	Total Uncertainty, ±(ppm of output+floor)		Resolution	Load Current[11]	Temperature Coefficient 0°C to 18°C, 28°C to 40°C
	50 Hz to 10 kHz[3]	20 kHz to 50 kHz[3]			
Standard: 100 to 1100V	800+0.1V	1200+0.15V	10 mV	200 mA[12]	50Hz to 10 kHz: ±(30 ppm of output+3 mV)/°C
Enhanced by 8506A: 100 to 600V	210+0.01V	610+0.01V	10 mV	200 mA[12]	20kHz to 50 kHz: ±(50 ppm output+5 mV)/°C

[11] Decreasing linearly from 200 mA at 100 Hz to 140 mA at 50 Hz.
[12] Maximum capacitive load of 1500 pF.

Multifunction Cardinal Point Resistance Specifications from 5100B:

Resistor Value	Total Uncertainty, ±ppm output	Mode	DMM-Supplied Test Current				Temperature Coefficient 0°C to 18°C 28°C to 40°C
			Power Coef. ppm/mW	Max Power	Max Volts	Max Amps	
1Ω	150	4-wire	0.1	1W	1V	1A	10 ppm/°C
10Ω	100	4-wire	0.3	1W	3V	300 mA	10 ppm/°C
100Ω	30	4-wire	0.3	1W	10V	100 mA	5 ppm/°C
1 kΩ	30	4-wire	0.3	1W	30V	30 mA	5 ppm/°C
10 kΩ	30	2-wire	0.3	1W	100V	10 mA	5 ppm/°C
100 kΩ	30	2-wire	0.3	1W	300V	3 mA	5 ppm/°C
1 MΩ	100	2-wire	0.2	100 mW	300V	300 μA	5 ppm/°C
10 MΩ	300	2-wire	0.02	10 mW	300V	30 μA	10 ppm/°C

Multifunction Current Output Specifications from 5100B:

Output Characteristics	Direct Current	Alternating Current[13] 50 Hz to 1 kHz
Ranges	200 μA, 2 mA, 200 mA, 2A; bipolar	200 μA, 2 mA, 20 mA, 200 mA, 2A
Total Uncertainty	±(150 ppm output+20 ppm range+0.01 μA)	±(500 ppm output+50 ppm range+0.02 μA)
Resolution	5 ppm range	5 ppm range
Compliance Voltage	10V to 200 mA and 2.1V to 2A	7V rms to 200 mA and 1.4V rms to 2A
Temperature Coefficient (0°C to 18°C, 28°C to 40°C)	±(10 ppm output+2 ppm range)/°C	±(25 ppm output+10 ppm range+0.2 μA)/°C

[13] The multifunction output can supply current to 5 kHz. There are 15 discrete frequencies over the entire range.

Boost Current Output Specifications from 5220A driven by 5100B: (optional)

Output Characteristics	Direct Current	Alternating Current 50 Hz to 5 kHz
Range	2A to 20A	2A to 20A
Total Uncertainty	±(250 ppm output + 1 mA)	50 Hz to 1 kHz: ±(700 ppm output + 1 mA) 1 kHz to 5 kHz: ±(700 ppm output + 1 mA) ×frequency in kHz
Resolution	5 ppm range	5 ppm range
Compliance Voltage	4V	3V rms
Temperature Coefficient (0°C to 18°C, 28°C to 40°C)	±(30 ppm output + 0.1 mA)/°C	±(30 ppm output + 0.1 mA)/°C

Low Frequency Sine Wave Output Specifications Using 5100B Wideband Output Option

Total Uncertainty and Flatness (into 50 Ohm):

Range	Total Uncertainty ±(% output + floor) at 1 kHz	Flatness % to 30 Hz	to 1 MHz	to 5 MHz	to 10 MHz	Resolution
300 μV to 1 mV	2.0 + 2.5 μV	0.3	0.25	0.6	0.6	10 nV
1 mV to 3.1623 mV	1.75 + 8.0 μV	0.3	0.25	0.25	0.6	100 nV
3.1624 to 10 mV	1.5 + 25 μV	0.3	0.25	0.25	0.6	100 nV
10 to 31.623 mV	1.25 + 80 μV	0.3	0.25	0.25	0.6	1 μV
31.624 to 100 mV	1.0 + 0.25 mV	0.3	0.25	0.25	0.6	1 μV
0.1 to 0.31623V	0.75 + 0.8 mV	0.3	0.25	0.25	0.6	10 μV
0.31624 to 1.0V	0.5 + 2.5 mV	0.3	0.25	0.25	0.6	10 μV
1.0 to 3.1623V	0.25 + 8.0 mV	0.3	0.25	0.25	0.6	100 μV

- **Frequency:**
  Range: 10 Hz to 10 MHz at discrete frequencies
  Resolution: One (most significant) digit
  Uncertainty: ±3%
- **Temperature Coefficient:** 0°C to 18°C, 28°C to 40°C:
  Amplitude: Add 0.1×1 kHz amplitude uncertainty per °C
  Frequency: Add 0.25% per °C

General Specifications

- **Temperature Range:**
  Operating: 10°C to 40°C
  Non Operating: −20°C to 60°C
- **Humidity:** 20% to 75% non condensing
- **Warm-up:** 2 hours to rated accuracy
- **Shock and Vibration:** Meets requirements of MIL-T-28800C for Type III, Class 5, Style E equipment
- **Bulk, Weight and Power:**

		1722A	5100B	8506A	CG 5001
Height	cm	13	22	11	19
	in	5.25	8.75	4.25	7.6
Width	cm	43	43	43	44
	in	17.0	17.0	17.0	17.5
Depth	cm	55	60	43	49
	in	21.5	23.75	17.0	19.2
Weight	kg	14	33	12	14
	lb	34	72	26	32
Power	Watts	175	200	24	65

- **Line Power:**
  Voltage: 100, 120, 220, 240V ac ± 10%
  Frequency: 50 to 60 Hz

Measurement Capability of 8506A Multimeter (7404B and 7449A)

Direct Voltage Measurement Specifications

Input Characteristics				Total Uncertainty, 6½ Digit Operation ±(ppm input + digits)		Temperature Coefficient 0°C to 18°C, 28°C to 40°C ±(ppm input + digits)/°C
Range	Maximum Displayed Voltage	Resolution	Input Ohms	Average	Normal	
100 mV	200.0000 mV	100 nV	≥10,000 MΩ	20+8	25+40	3+5
1V	2.000000V	1 μV	≥10,000 MΩ	12+6	15+8	3+1
10V	20.00000V	10 μV	≥10,000 MΩ	See Note 14	10+8	2+0.5
100V	128.0000V	100 μV	10 MΩ	15+6	18+8	3+1
1000V	1200.000V	1 mV	10 MΩ	15+6	18+8	3+0.5

[14] 7½ digit operation with 20.000000 count at full scale and 1 μV resolution, uncertainty 8 ppm input plus 60 digits.

- **Normal Mode Rejection:** 100 dB at 60 Hz or 95 dB at 50 Hz
- **Common Mode Rejection:** 160 dB at 60 Hz with 1 kΩ unbalance in either lead

Alternating Voltage Measurement Specifications 5½-Digit Operation

Input Characteristics			
Range	Maximum Displayed Voltage	Resolution	Input Impedance
100 mV	125.000 mV	1 μV	1 MΩ+1% shunted by <180 pF on all ranges
300 mV	400.000 mV	1 μV	
1V	1.25000V	10 μV	
3V	4.00000V	10 μV	
10V	12.5000V	100 μV	
30V	40.0000V	100 μV	
100V	125.000V	1 mV	
500V	600.000V	1 mV	

High Accuracy Mode,[15] Total Uncertainty, 5½-Digit Operation							
	Input Frequency vs. Percent Input Amplitude Uncertainty						
Range	10 to 40 Hz	40 Hz to 20 kHz	20 to 50 kHz	50 to 100 kHz	100 to 200 kHz	200 to 500 kHz	500 kHz to 1 MHz
100 mV	0.08	0.026[16]	0.06	0.2	0.6	1.5	3.5
300 mV to 10V	0.08	0.016	0.06	0.2	0.5	1.5	3.5
30V	0.08	0.016	0.06	0.2	0.5	3.5	12.0
100V	0.08	0.016	0.06	0.2	1.0	3.5	—
500V	0.08	0.016	0.06	0.2	—	—	—

[15] Enhanced and Normal Modes of aV measurement are available. See the 8506A data sheet.
[16] Add 5 digits (5 μV) to the % reading.

- **Temperature Coefficient:** (0°C to 18°C, 28°C to 40°C): 0.1×90 day uncertainty
- **Common Mode Rejection:** >120 dB, dc to 60 Hz with 100Ω in either lead

Resistance Measurement Specifications (optional):

Ohms Range	Full Scale Ohms	Number of Digits	Resolution in Ohms	Test Current	Total Uncertainty ±(ppm input + digits)	Temperature Coefficient 0°C to 18°C, 28°C to 40°C ±(ppm input + digits)/°C
10Ω	20.0000Ω	5½	100 μΩ	10 mA	50+20	8+1.5
100Ω	200.0000Ω	6½	100 μΩ	10 mA	30+14	7+2
1 kΩ	2.000000 kΩ	6½	1 mΩ	1 mA	30+8	7+2
10 kΩ	25.00000 kΩ	6½	10 mΩ	78 μA	30+8	7+2
100 kΩ	250.0000 kΩ	6½	100 mΩ	7.2 μA	30+8	7+5
1 MΩ	4.10000 MΩ	5½	10Ω	4.5 μA	30+1	10+1
10 MΩ	35.0000 MΩ	5½	100Ω	450 nA	200+1	50+1
100 MΩ	265.000 MΩ	5½	1 kΩ	56 nA	500+1	200+1

Oscilloscope Calibration (7449A only)

Oscilloscope calibration pulse output specifications using Tektronix CG5001 Oscilloscope Calibration Generator[17]

Voltage (Amplitude Mode): Square waves or direct voltage used to calibrate vertical axis.

Range	40 μV to 200V (1-2-5 steps with multiplier)
Multipliers	1, 2, 3, 4, 5, 6, 8, and 10 divisions
Polarity	Positive from case ground
Uncertainty	±(0.25+1 μV)
Frequency	40 to 80 mV: 10 Hz to 100 kHz 0.1 to 10V: direct voltage or 10 Hz to 100 kHz 12 to 200V: direct voltage or 10 Hz to 10 kHz
Adjustment	Amplitude can be varied ±9.9% from nominal

Current (Amplitude Mode): Used to calibrate current probes.

Range	1 to 100 mA (1-2-5 sequence)
Multipliers	1, 2, 3, 4, 5, 6, 8, and 10
Uncertainty	±(0.25% + 2 μA)
Frequency	Direct current or 10 Hz to 1 MHz (decade steps)
Droop	≤1%
Adjustment	Amplitude can be varied ±9.9% from nominal

Edge (Amplitude Mode): Used to calibrate vertical risetime.

Low Range:	20 mV to 1V p-p (1-2-5) steps with multiplier
Multipliers	1, 2, 3, 4, 5, 6, 8, and 10
Polarity	Positive or negative transitions relative to case ground
Rise Time	≤1.3 nS (also applies to fall time)
Aberrations	±2%
Flatness	±0.5%, after first 10 nS
Frequency	10 Hz to 1 MHz (decade steps)
Adjustment	Amplitude can be adjusted to ±9.9% from nominal
Termination	50Ω
High Range:	1.2 to 100V (1-2-5) steps with multiplier
Polarity	Positive transitions only (negative voltage rising to ground)
Rise Time	<100 nS
Aberrations	±2% of square wave amplitude
Flatness	±0.5%, after first 500 nS
Frequency	10 Hz to 100 kHz (decade steps)
Adjustment	Amplitude can be adjusted to ±9.9% from nominal
Termination	≥1 MΩ

Markers (Timing Mode): Used to calibrate time base accuracy.

Range	10 nS to 5S (1-2-5 steps)
×10 Magnifier	Increase marker rate by factor of ten (0.1 μS to 5S range)
Uncertainty	±0.01%
Amplitude	1V minimum into 50Ω
Adjustment	Time can be adjusted to ±9.9% from nominal

Slewed Edge (Timing Mode): Used to calibrate very fast time base accuracy.

Range	0.4 nS to 100 nS (1-2-5 step plus 0.4 nS)
×10 Magnifier	Increases slewed edge by factor of ten (5 nS to 100 nS range)
Uncertainty	±0.01%
Position	±40 pS uncertainty in position of edge
Amplitude	1V minimum into 50Ω
Adjustment	Time can be adjusted to ±9.9% from nominal

Trigger Output: Used to calibrate external trigger mode.

Normal Mode	Slaved to marker rate from 5S to 100 nS and remains at 100 nS for faster rates
Slewed Rate Mode	One trigger per slewed edge
All Other Modes	Slaved to output frequency
Division	The trigger rate can be reduced by factors of 10:1 and 100:1 (not available in slewed edge mode)
Amplitude	1V minimum into 50Ω

Pulse Head: Used to calibrate very fast vertical risetimes.

Amplitude	1.1V peak, ±5% into 50Ω
Polarity	Positive or negative transitions from case ground
Rise Time	≤200 pS
Aberrations	≤3% of pulse amplitude; not to exceed 4% p-p for adjacent peaks for zero to 50 nS
Frequency	100 Hz to 100 kHz (decade steps)
Adjustment	Amplitude can be adjusted ±9.9% from nominal

Comparator Head: Used to calibrate built-in calibrator output.

Input	Alternating Voltage: ±40 μV to +100V, 10 Hz to 1 MHz, squarewave Direct Voltage: −100 mV to +100V
Resistance	Open: Unterminated (the resistance of the oscilloscope input) 50Ω: 50Ω±1% in 50Ω position. Maximum voltage is ±5V peak in the 50Ω position.
Chop	Frequency: 30 Hz nominal (Auto). Auto Timeout: Internally selectable at 0.5, 1, or 2 minutes For complete specifications see the Tektronix CG5001 manual.

[17] Registered trademark of Tektronix, Inc.

5200A-800 software, 4-8
7404A, 3-5
    Application notes, 3-8
    Description of, 3-5
    Installing, 3-5
    Unpacking, 3-9
7404B, 3-13
    Application notes, 3-16
    Description of, 3-13
    Installing, 3-13
    Unpacking, 3-16
7405A, 3-52
7409A, 3-23
    Application notes, 3-25
    Description of, 3-23
    Installing, 3-26
    Unpacking, 3-26
7410A, 3-52
7411A Procedures, 4-8
7411B Procedure, 4-10
    General information, 4-10
7411B Manual set, 1-4
7449A, 3-30
    Application notes, 3-33
    Description of, 3-30
    Installing, 3-30
    Unpacking, 3-34

A123-CO-nn and A123-PE-nn, 3-53

Adding printer to system, 4-71
Application notes, 3-8, 3-16, 3-25, 3-33, 3-47
Automated calibration system, 2-2
Automated calibration workstations, 2-2

Bar code reader, 4-72
    Connecting to 1722A
    Equipment, 4-72
    INTEMEC 9510, Setting up, 4-74

Calibration clusters, 2-2, 3-1
Calibration history management software, 4-10
Calibration workstations, 3-1
Changing the 7411A STRTUP.CMD files, 4-77
Choosing System for Workload, 4-6
    New installations, 4-6
    Upgrading existing system, 4-9
Choosing software for system, 4-9
    PGE and INT operating code, 4-9
Combined 7405A/7410A, 3-49
COMMND.INT file, 4-77
    Modification of, 4-78
Computation and control, 3-41
Computer-aided calibration, 2-1
Configuration decision factors, 4-5
Configuration Manual, organization of, 1-1

Data sheets, Appendix
DC and low-frequency stimulus, 3-46

Editing procedure, 4-69
    Editing for different instruments, 4-70
    RUNE, 4-70
    Why edit?, 4-69
FIT and WPV, 4-12
Fluke example procedures, 4-11
Functional Integration Tests (FIT), 3-3

Hard Disk, 4-82

Installing 7404A, 3-5
Installing 7404B, 3-13, 3-16

Installing 7409A, 3-23, 3-25
Installing 7449A, 3-30,3-32
Installing custom workstations, 3-53
Installing standard workstations, 3-52
Installing user-defined system, 3-41

Manuals in this binder, 1-1
Measurement, 3-46

New installations, 4-6

Operating code, 4-14
    Overview, 4-14
    Step-by-Step Description, 4-15ff
Performance verification (PV or WPV), 3-3
PGE and INT operating code, 4-9
Printer, addition of, 4-71
    Port connections, 4-71
    Printer information, 4-72
    Serial port characteristics, 4-71
Pulse and waveform stimulus, 3-42

RF stimulus, 3-46
RUNE, 4-70

Safety information, 1-5
Specifications, 1-4
STRTUP.CMD file, 4-75
    Modification of, 4-77
Step-by-step configuration description, 4-15

Translating a procedure, 4-53
    Copying BASIC Routines, 4-57
    From 7411A Disks to 7411B Disks, 4-55
    From Pre-7411A to 7411A
    Introduction, 4-53

Types of workstations, 3-47

UDS description, 3-41
Unpacking and installing the 7404A, 3-8
Unpacking and installing the 7404B, 3-16

Unpacking and installing the 7409A, 3-26
Unpacking and installing the 7449A, 3-34
Upgrading existing systems, 4-9
User-configured arrangements, 3-54
User-defined System, 3-41
    Application Notes, 3-47
    Installing, 3-41
    Computation and Control, 3-45
    Description of, 3-41
    measurement, 3-46
    Overview, 3-41
User's group procedures, 4-12

Why translated procedure may need editing, 4-69
Workstation, 3-47
    Application information, 3-53
    Definitions, 3-51
    Installation of Custom Workstations, 3-53
    Installation of Standard Workstations, 3-51

5200A

MODELS 5200A-90x
CHARACTERIZATION SERVICES

MODEL 5200A-800
OPERATION AND CALIBRATION SOFTWARE

Calibrator Enhancement Manual

P/N 805416
JULY 1985
©1985 John Fluke Mfg. Co., Inc. All rights reserved.

FLUKE®

TABLE OF CONTENTS

Section 1
Introduction and Specifications

INTRODUCTION 1- 1
HOW TO USE THIS MANUAL 1- 1
WHAT IS CHARACTERIZATION? 1- 2
FLUKE 5200A/5205A/5215A ENHANCEMENTS 1- 2
GETTING YOUR 5200A CHARACTERIZED 1- 2
SPECIFICATIONS 1- 3

Section 2
Automated 5200A-800 Operation

INTRODUCTION 2- 1
SAFETY FEATURES 2- 1
SOFTWARE FAMILIARIZATION 2- 2
Summary of Controls and Indicators - DATA ENTRY MODE 2- 4
Summary of Controls and Indicators - EDIT MODE 2- 8
SOFTWARE SETUP 2-10
Make a Working Copy 2-10
Copying the 5200.DAT File 2-11
Changing the IEEE-488 Bus Address 2-12
SOFTWARE STRUCTURE 2-12
INSTRUMENT SETUP 2-13
Controller Display Alignment 2-13
Instrument Setup 2-14

Section 3
Manual Corrections

INTRODUCTION 3- 1
SAMPLE TABLE OF CORRECTED VOLTAGES 3- 1
DIRECT CORRECTION 3- 2
INTERPOLATED CORRECTION 3- 2
Example 1: Interpolation Between Frequency Points 3- 3
Example 2: Interpolation Between Voltage Points 3- 4
Example 3: Interpolation Between Voltage and Frequency Points .. 3- 6

Section 4
Characterization Procedure

INTRODUCTION 4- 1
REQUIRED EQUIPMENT 4- 1
GETTING FAMILIAR 4- 2
INITIAL PREPARATION 4- 8
540B OPERATING CHECKS 4- 8
EQUIPMENT SET-UP 4-10
ENTERING 540B CHARACTERIZATION CONSTANTS 4-12
THE CHARACTERIZATION PROCEDURE 4-13
Sequential Characterization 4-14

Specific-Point Characterization 4-19
Characterization Table Notes 4-19
Printing Out the Table 4-21
SPECIAL-POINT CHARACTERIZATION 4-21
CHANGING SOFTWARE IEEE-488 BUS ADDRESSING 4-25

LIST OF TABLES

Number Page

1-1 5200A/5205A/5215A Characterized-Point Absolute Uncertainty 1- 4
1-2 5200A/5205A/5215A Absolute Uncertainty 1- 5
3-1 Sample 5200A-90x Table of Corrected Voltages 3- 2
4-1 Required Equipment 4- 2
4-2 Required 540B Characterization Points and Uncertainties 4- 2
4-3 Display Table of Characterization Constants 4-20

LIST OF FIGURES

Number Page

2-1 Start-Up Display 2- 2
2-2 Data Entry Control Display 2- 4
2-3 Edit Control Display 2- 8
3-1 Example 1 ..... 3- 3
3-2 Example 2 ..... 3- 5
3-3 Example 3 ..... 3- 7
4-1 Main Calibration Menu 4- 4
4-2 Calibration Program Flowchart 4- 7
4-3 Equipment Setup, 5200A 4-10
4-4 Equipment Setup, 5205A or 5215A 4-11
4-5 Characterization Point Display 4-15
4-6 AC/DC Transfer Control Display 4-16
4-7 AC Null Control Display 4-17
4-8 Special-Point Characterization Menu 4-22
4-9 Special-Point Characterization Display 4-24

Section 1
Introduction and Specifications

INTRODUCTION

The established excellent stability of the Model 5200A Calibrator and the Models 5205A and 5215A Amplifiers offers an opportunity to further enhance accuracy performance by using traditional metrology techniques in an innovative way. This manual describes a package of performance options that integrate characterization with automation. Characterization gives significantly better accuracy. Automation removes tedium and specialized skill requirements, making this enhanced performance productive and easy to use.

The 5200A Alternating Voltage Calibrator is a precision high-performance alternating voltage source with exceptional stability and accuracy over a broad frequency range. The 5205A and 5215A Power Amplifiers are precision fixed-gain amplifiers that extend 5200A output levels to 1100V and 200 mA, with the capacitive and inductive drive capabilities to accomplish calibration in a system installation without isolating the meter. Model 5205A is a general purpose dc-coupled amplifier. Model 5215A is an ac-coupled amplifier designed specifically for use with the Model 5200A Calibrator. In use, either amplifier is completely controlled by the 5200A front panel or by an instrument controller through a 5200A-05 IEEE-488 Interface. Each unit is specified over a wide 0°C to 50°C operating range for use in both laboratory and manufacturing environments.

HOW TO USE THIS MANUAL

You do not need to read this entire manual unless you plan to develop a compatible table of correction factors in your standards laboratory.

If you are unfamiliar with the use of characterization tables in calibration, a discussion of characterization fundamentals follows in this Section 1. Section 1 also includes 5200A and 5205A/5215A specifications, with and without these enhancements.

Section 2 guides you though your initial use of 5200A-800 software to operate a 5200A calibrator. You will find the display screens easy to understand.

Section 3 describes, with worked-out examples, how to manually use a 5200A-90x characterization table to achieve enhanced 5200A specifications without the need for an instrument controller.

Section 4 is the procedure for developing a table of 5200A-90x compatible correction factors in your standards laboratory. While requiring additional equipment and skill, this procedure is structured and easy to follow. Provisions are included for calibrating any or all of the points in the standard 5200A-90x correction table, as well as up to 50 special points customized to meet the needs of the meters you are responsible for calibrating.

WHAT IS CHARACTERIZATION?

Characterization is a process of measuring a particular calibrator's errors at selected points, using traceable transfer standards, and recording these errors in a table. When the calibrator is later used at one of these points, this known error can be compensated for. Also, if the characteristics of the calibrator are known, mathematical interpolation can be used for points other than those in the characterization table.

It is practical to use specific characterization points since meters are commonly calibrated at specified voltage and frequency points.

FLUKE 5200A/5205A/5215A ENHANCEMENTS

Options 5200A-90x are characterization services for 5200A calibrators and 5205A or 5215A amplifiers. A standard set of correction points compatible with 5200A-800 and 7411A software is included. You can also request additional correction points appropriate for the meters that you will be calibrating. A certified traceable table of correction factors is supplied in both written and compatible disk form.

Option 5200A-800 is a software package that uses the touch-sense display of a Fluke 1722A or 1720A Instrument Controller to operate a 5200A calibrator in a simplified manner similar to a Fluke 5440B Direct Voltage Calibrator. It uses a 5200A-90x characterization table for accuracy corrections, and automatically interpolates for voltages and frequencies not on the table. When a table of correction factors is not provided, it operates the calibrator to standard specifications.

This software controls all calibrator functions through the touch sense display of the 1722A or 1720A to simplify operation. You can select and edit output frequency and voltage, and select operate/standby modes, phase lock, and external sense. In operation, the controller displays calibrator output and UUT (Unit Under Test) uncertainty in your choice of percentage, volts, or ppm.

Model 7411A software, scheduled for release in Fall 1985, is general-purpose system software for automated calibration workstations. It executes stored procedures that were generated by its Procedure Generator/Editor. When operating a 5200A Calibrator, it automatically generates corrections from a 5200A-90x compatible characterization table when one is available to it.

GETTING YOUR 5200A CHARACTERIZED

5200A-800 and 7411A software will operate the calibrator and amplifier to standard specificatons without a table of correction factors. However to enhance accuracy for your 5200A and 5205A or 5215A, a 5200A-90x characterization table is required. There are two ways to accomplish this:

1. Order 5200A-90x characterization service from Fluke.

Whether you are purchasing a new 5200A (and optional 5205A or 5215A Precision Amplifier) or already own a 5200A, characterization service is available from Fluke. Order one of the following services:

MODEL	FOR...
5200A-900	New-purchase 5200A/5215A
5200A-901	Customer-owned 5200A and 5205A or 5215A
5200A-902	New-purchase 5200A
5200A-903	Customer-owned 5200A

5200A-900 and 5200A-902 services are available from Fluke when included on a purchase order for a 5200A calibrator or 5200A/5215A cluster. 5200A-901 and 5200A-903 are available only through Fluke Technical Service Centers.

A table of correction factors is supplied in written form and on a disk compatible with 5200A-800 software.

2. Generate the table of correction factors in your own Standards Laboratory.

   5200A-800 software includes programs designed to make this easy. Equipment requirements and procedures are described in Section 4.

SPECIFICATIONS

Table 1-1 gives **Characterized-Point specifications.** These are absolute uncertainties at the points in a 5200A-90x table. Similar uncertainties can be expected for any special points you select for the meters in your calibration workload.

Table 1-2 gives uncertainty specifications for the Calibrator and a 5205A or 5215A Amplifier under its control. As you can see, characterization enhances 5200A performance dramatically.

Basic Instrument specifications are for a standard 5200A. **Characterized Instrument specifications** give the uncertainty obtained by interpolating between the points of a 5200A-90x table using 5200A-800 or 7411A software, or the manual techniques described in Section 3.

Absolute uncertainties include the error contributions of standards and of transfer techniques used here at Fluke. When calibrated by Fluke, these specifications are valid for 180 days, and are certified traceable to the U.S. National Bureau of Standards. Certified traceability to other national standards is also available at many Fluke Technical Service Centers throughout the world.

If you prepare a 5200A-90x compatible table of correction factors using professional metrology techniques and the procedures described in Section 4 of this manual, you can use these uncertainty specifications with confidence.

Voltage	Characterized-Point Absolute Uncertainty[1,2], ±ppm								
	Frequency, Hz								
	50	100	200	1k	2k	10k	20k	50k	100k
0.5	125	125	-	125	-	125	-	210	450
1	120	120	120	120	120	120	120	200	450
3	130	130	-	130	130	130	-	220	450
10	120	120	120	120	120	120	120	200	450
30	130	130	-	130	-	130	-	220	450
100	120	120	120	120	120	120	120	200	450
300[3]	190	190	-	190	-	190	-	630	-
1000[3]	180	180	180	180	180	180	200	610	-

Notes:

1. Includes transfer standards, DC reference source, and allowances for calibration technique.
2. Requires 5200A-900, -901, -902, or -903.
3. Output is through 5205A or 5215A amplifier.

Table 1-1. 5200A/5205A/5215A Characterized-Point Absolute Uncertainty

Voltage Ranges	Absolute Uncertainty			
	Basic Instrument		Characterized Instrument[2]	
	Frequency Hz	±(ppm setting + uV)	Frequency Hz	±(ppm setting + uV)
1 mV[3] 10 mV	10 - 30 30 - 20k 20k - 100k 100k - 1M	1000 + 10 200 + 10 500 + 20 3300 + 30		
100 mV	10 - 30 30 - 20k 20k - 100k 100k - 1M	1000 + 10 200 + 10 500 + 20 3300 + 30	50 - 100 100 - 20k 20k - 50k 50k - 100k	150 + 10 145 + 10 250 + 20 470 + 20
		±(ppm setting + ppm range)		±(ppm setting + ppm range)
1 V 10 V 100 V	10 - 30 30 - 20k 20k - 100k 100k - 1M	1000 + 50 200 + 20 500 + 50 3300 + 300	50 - 100 100 - 20k 20k - 50k 50k - 100k	150 + 20 145 + 15 250 + 20 470 + 30
1000 V[4]	10 - 30 30 - 20k 20k - 50k 50k - 100k	1200 + 50 400 + 40 800 + 50 1000 + 100	50 - 100 100 - 10k 10k - 20k 20k - 50k	210 + 20 200 + 20 220 + 20 630 + 30

Notes:

1. Includes transfer standards, DC reference source, and allowances for calibration technique.
2. Requires 5200A-900, -901, -902, or -903.
3. Applies for measuring instruments with less than 2 MHz bandwidth.
4. Output is through 5205A or 5215A amplifier.

Table 1-2. 5200A/5205A/5215A Absolute Uncertainty

Section 2
Automated 5200A-800 Operation

INTRODUCTION

This section tells you how to use **5200A-800 Software** to operate a 5200A Calibrator with the touch-sensitive display of a Fluke instrument controller. The calibrator can operate a 5205A or 5215A Amplifier. Either a 1722A or 1720A instrument controller may be used. And when a 5200A-90x correction table is available on its disk, the software enhances calibrator accuracy automatically.

The 5200A calibrator is connected through its optional 5200A-05 IEEE-488 interface to the controller. In operation, the controller touch-display becomes the user interface for the calibrator. All 5200A operating controls except **POWER**, **CONTROL**, and **VOLTAGE ERROR -%** are accessible on the controller display. POWER is activated manually, and CONTROL is set to **REM** (remote). The **VOLTAGE ERROR - &** editing function is accomplished to full 1,199,999 count resolution on the controller touch-display.

The table of 5200A and 5205A or 5215A corrections may also be used by 7411A Computer-Aided Calibration Software. This is described in a separate manual.

SAFETY FEATURES

WARNING

HIGH VOLTAGE
is used in the operation of this equipment.

DEATH ON CONTACT
may result if you do not understand and follow safety procedures.

WHEN OPERATED BY 5200A-800 SOFTWARE, CALIBRATOR STATUS AND OUTPUT VOLTAGE ARE NOT AS SELECTED ON THE CALIBRATOR FRONT PANEL.

In Operate Mode, Calibrator output is energized whenever **OPERATE** is backlit on the OPERATE/STANDBY touch-switch on the controller Data-Entry or Edit display screens. When OPERATE mode is touch-selected, the backlit voltage level display, top-center on the controller screen, is changed from **Selected:** to **Output:**, and calibrator or amplifier output is energized.

Calibrator and amplifier output may be de-energized at any time by:

- switching 5200A POWER **OFF**, or
- selecting **STANDBY** on the OPERATE/STANDBY touch-switch on the controller display screen.

Calibrator output is not energized by the controller during start-up sequence or when **Demo mode** is selected.

While nothing can take the place of professional safety procedures, the 5200A Calibrator, the 5205A and 5215A Amplifiers, and 5200A-800 software include safety features that help you ensure safe operation:

- When power is turned on, the calibrator starts up in **STDBY** (standby) mode regardless of the condition it was last in. 5200A-800 software initializes in **STANDBY** mode with 0.1 mV selected.

- If the calibrator sense leads are accidentally disconnected in **External-Sense** mode, output is prevented from rising more than 2V above the selected setting.

- The calibrator switches to **STDBY** (standby) whenever the 1000V range is manually selected. 5200A-800 software switches to **STANDBY** mode whenever you increase the selected voltage past 20V, and again past 120V.

SOFTWARE FAMILIARIZATION

As a first step, we suggest you use 5200A-800 software in **Demo Mode** to familiarize yourself with its operation without the need for additional equipment. The only difference in Demo Mode is that IEEE-488 Bus commands are not generated. This allows the software to run on a controller with no other equipment connected.

What follows is a description of each software display, and each functional selection that you can make. Select Demo Mode, and you will be able to try each function.

Getting started is as simple as placing the 5200A-800 disk in your 1722A or 1720A instrument controller and either turning it **ON** or pressing **RESTART**. After software loading, the start-up display shown in Figure 2-1 will appear.

The Start-Up Display gives information and presents some choices. Figure 2-1 shows the display when there is no correction data table available on the disk. When a valid correction data table is available, an expiration date is displayed in place of **Not Meaningful**, and either one or two serial numbers are displayed in place of **NO CORRECTION DATA**. When only a 5200A serial number is displayed, the table does not include corrections for a 5205A or 5215A amplifier.

The software will operate the calibrator and amplifier regardless of correction factors or expiration date. Correction data is used if it is available.

> **Verify that displayed serial number(s) are for calibrator (and amplifier) that you are using, and that the expiration date has not passed.**

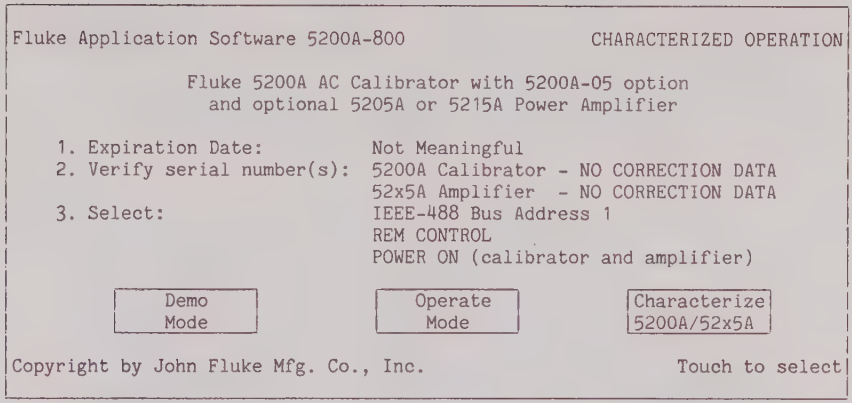


Figure 2-1. Start-Up Display

Three choices are presented:

Demo Mode

Touch-select **Demo Mode** to get the display of Figure 2-2. Demo Mode is identical to operate mode, except that it allows the software to operate without the calibrator connected. No IEEE-488 Bus commands are sent. Demo Mode is provided to help you become familiar with the software without generating calibrator voltages.

Operate Mode

Touch-select **Operate Mode** to get the display of Figure 2-2. Operate Mode is the normal mode of operation. IEEE-488 Bus commands are sent to the 5200A Calibrator as it is operated through the touch-sensitive display of the controller. If a 5205A or 5215A amplifier is connected, it is in turn operated by the 5200A calibrator.

Characterize 5200A/52x5A

Touch-select **Characterize 5200A/52x5A** to start up a program that generates a table of correction factors for a 5200A and a 5205A or 5215A amplifier. Refer to Section 4 for further information.

Summary of Controls and Indicators - DATA ENTRY MODE

Data Entry Mode is reached from the Start-Up display by touch-selecting **Demo Mode** or **Operate Mode**. It may also be reached from Edit Mode by touch-selecting **Select Data Entry**.

The Data Entry Control Display is shown in Figure 2-2. Following is a summary describing each of its controls and indicators.

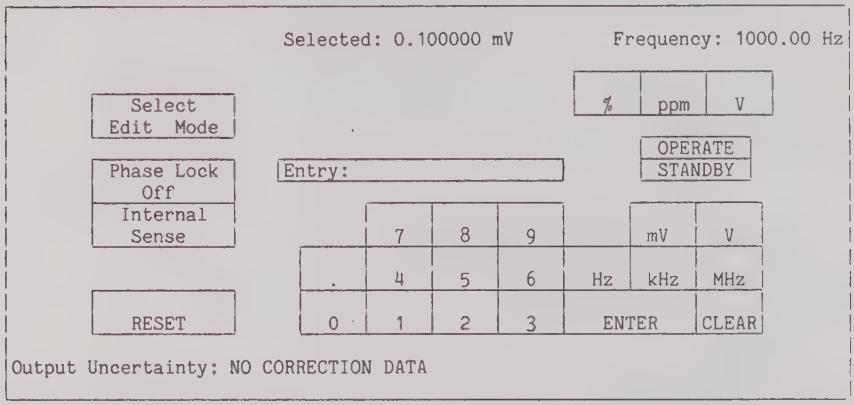


Figure 2-2. Data Entry Control Display

RESET

Touch-select **RESET** to reset the software and the calibrator to start-up condition. The Start-Up screen (Figure 2-1) is displayed, and the calibrator is reset to STANDBY, 0.100000 mV, and 1000.00 Hz. This allows you to leave Demo Mode and select Operate Mode.

Selected: 0.100000 mV
Output: 0.100000 mV

Indicates the current selected output voltage level. Reads **Selected:** in STANDBY mode. Reads **Output:** in OPERATE mode, with the calibrator energized to the indicated level.

Frequency: 1000.00 Hz

Indicates the current selected output frequency.

Select
Edit Mode

Touch-select **Select Edit Mode** to re-draw the keypad with edit keys as shown in Figure 2-3. See the description of Edit Mode below.

Phase Lock
Off

This is an alternating switch. Touch-select **Phase Lock Off** to send a phase-lock command to the 5200A. **Off** is replaced by **On**. This instructs the calibrator to lock phase with an external signal supplied to it through its rear **PHASE LOCK INP** connector.

When selected again, phase lock is turned off and the switch again displays **Off**.

Internal
Sense

This is an alternating switch. Touch-select **Internal Sense** to request external voltage level sensing. If it is available for the current voltage level, the touch-switch display will change to **External Sense**. The calibrator **SENSE HI** and **SENSE LO** lines must be connected to the meter being calibrated at its input terminals.

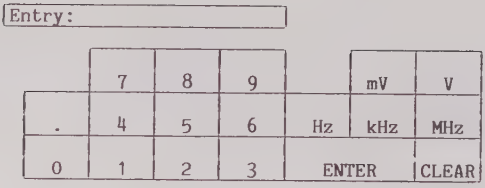
The message **Not available at this output...** is displayed along the lower right of the screen when external sense is requested for voltage settings below 120 mV and at or above 120V. Press either **CLEAR** or **Internal Sense** to clear this message and re-enable the keypad.

OPERATE
STANDBY

This is an alternating switch. Touch-select **OPERATE/STANDBY** to select operate or standby mode. The active mode is backlit on the display switch. Start-up condition is STANDBY. When **OPERATE** is selected, the **Selected:** display changes to **Output:** and the calibrator is energized with the voltage and frequency displayed on the top of the controller screen.

WARNING

The controller display is the only indication of calibrator output voltage. 5200A front panel settings will NOT indicate true output.



The entry keypad is used for entering voltage and frequency. Entries accumulate in the entry window until you touch **ENTER** or **CLEAR**. The proper sequence is to enter a numeric value, and then to identify it with a label: **mV**, **V**, **Hz**, **kHz**, or **MHz**. Then, either touch **ENTER** if the entry is correct, or **CLEAR** if you would like to re-enter it. When **ENTER** is touched, the entry is checked against performance limits, and transferred to the **Selected:** or **Output:** and **Frequency:** windows.

For OPERATE mode, two voltage safety thresholds are established: 20V and 120V. When a voltage entry exceeds one of these thresholds, and the previous level was less, calibrator status is automatically switched to STANDBY. You must then touch **OPERATE/STANDBY** to re-energize calibrator output.

When an entry is attempted without an identifying label, the message **Select voltage or frequency units...** is displayed on the right half of the bottom line. Touch a voltage or frequency label, or touch **CLEAR** to proceed.

When an entry is attempted that is beyond the performance limits of the calibrator, it is not accepted and the message **Entry is beyond amplitude limits...** is displayed. Press **CLEAR** to delete the entry and re-enable the keypad.

This is a dual-purpose key. Touch-select **CLEAR** once to clear information from the **Entry:** window. Touch-select **CLEAR** twice to reset calibrator status to STANDBY, and output display to **Selected: 0.100000 mV**. Frequency is not affected.

Output Uncertainty: NO CORRECTION DATA

Displays the absolute uncertainty of the selected output level, including a floor calculation. Displays **NO CORRECTION DATA** when a 5200A-90x table of correction factors is not available on the disk.

This uncertainty is only valid for the serial-numbered calibrator (and amplifier) for which the correction table was created, and prior to its expiration date. When the table was created by Fluke, it is

certified by Fluke to be true and traceable to the national standards bureau cited on the written certification that was supplied with it.

The displayed uncertainty will automatically drop when a point on the table of corrections is selected, allowing it to be used directly. Try, for example, 1V at 10kHz, and you will see 120 ppm. However, if you select a custom point that you added to the table, the displayed uncertainty will be the interpolated value even though the more accurate correction is being used.

These switches control the format in which **Output Undertainty:** is displayed. They also control the format of the Edit Mode **UUT Error:** display.

The designations **%** and **ppm** are relative to the current output voltage (ppm = parts per million, 100 ppm = 0.01%). **V** is the absolute magnitude of voltage uncertainty for the current output voltage.

Since display resolution is limited to three digits, you can often get more information from the **ppm** display than from **%**.

Summary of Controls and Indicators - EDIT MODE

Edit Mode is reached from Data Entry Mode by touching **Select Edit Mode**. The Edit Control Display is shown in Figure 2-3. Some controls and indicators remain unchanged. Following is a summary of each added control and indicator.

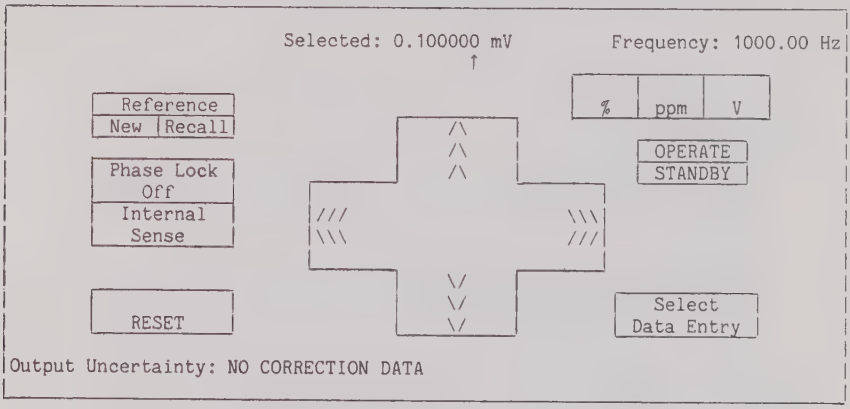


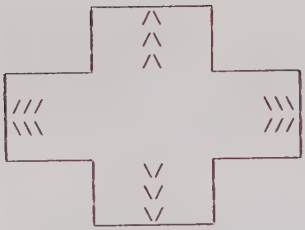
Figure 2-3. Edit Control Display

Select Data Entry

Touch-select **Select Data Entry** to re-draw the edit keys with the data-entry keypad, and return to Data Entry mode as shown in Figure 2-2.

↑

Indicates the digit that will be changed by touching the edit control.



This is the edit control area. Touch left or right to move the ^ digit indicator and select a digit for editing. Then touch up or down to increase or decrease that digit. Hold it down, and it will repeat at a slow rate that is easily managed while you are looking at the meter being calibrated.

Normal technique is to set voltage and frequency initially to the nominal setting called for in the meter calibration procedure. Then use Edit Mode to make adjustments as required to get a correct meter reading. The error can then be read directly from the display indicator described next.

UUT Error: -10.0 ppm

Indicates the difference between the reference voltage (usually the originally selected output voltage) and the edited value. **UUT Error:** does not appear until an editing change is done.

The format of the **UUT Error:** display can be changed by touching the **%**, **ppm**, or **V** keys.

Reference	
New	**Recall**

This is a dual switch. The reference voltage is normally the value that was initially entered, prior to editing changes. Touch-select **Recall** to re-establish output to that initial level. Touch-select **New** to define the voltage currently in the **Selected:** or **Output:** window as a new reference voltage.

Note that **UUT Error:** is simply the difference between the reference voltage and the current output voltage. Since it is only displayed when there is a difference, it disappears when you touch-select **New Reference**.

Make a Working Copy

Your 5200A-800 disk should be protected in a safe place. We suggest that you leave the write-protect tab in place and make a working copy. Use the same FUP whole-copy **/W** procedure that you would to duplicate any other disk.

With E-Disk...

If your controller has expansion memory (or 1720A E-Disk), 5200A-800 software will automatically configure and format it for you on start-up. Use this procedure:

1722A	1720A	Comments
(Insert 5200A-800 disk)		
<RESTART>	<RESTART>	Start up the software
<CTRL>C	<CTRL>C	Stop operating software
---	EXIT	Exit BASIC (1720A only)
FUP	FUP	File Utility Program
EDO:=MFO:/W	EDO:=MFO:/W	Copy disk onto E-Disk
(file name list)	(file name list)	
(Insert blank disk)		
MFO:/F@	MFO:/F	Format the blank disk
MFO:=EDO:/W	MFO:=EDO:/W	Copy E-Disk onto disk

If you are using a 1720A, and would like to limit the copy to 1720A files, watch for the message **Copying CALC.BAL ...** and type **<CTRL>C**. FUP will complete copying that file and then stop. If you do not do this, the 1720A will stop and indicate an error when one of the 1722A files overruns its capacity. This causes no problem except that the disk is needlessly full.

Without E-Disk...

If your controller does not have expansion memory (or 1720A E-Disk), you can still make a working copy. You will have to swap disks a few times to complete the copy. The procedure is similar, except that you must tell the FUP whole-copy **/W** procedure where in the directory to continue copying after each swap:

1722A	1720A	Comments
(Insert 5200A-800 disk)		
<RESTART>	<RESTART>	Start up the software
<CTRL>C	<CTRL>C	Stop operating software
---	EXIT	Exit BASIC (1720A only)
FUP	FUP	File Utility Program
(Insert blank disk)		
MFO:/F@	MFO:/F	Format the blank disk
EDO:/C-1	---	Configure main memory
(Insert 5200A-800 disk)		
EDO:=MFO:/W	MMO:=MFO:/W	Copy from disk
(file name list)	(file name list)	

```
?No room on device      ?No room on device
```

At this point, the controller memory does not have room for the next file. The 1722A helps you out by telling you the name of the file that would not fit, so you know where to start next time. Write down that file name. If you are using a 1720A, write down the last file that was copied.

Continuing the procedure:

```
        (Insert blank disk)
MF0:=ED0:/W             MF0:=MM0:/W             Copy onto disk
(file name list)        (file name list)
        (Insert 5200A-800 disk)
 ---                    <PAGE MODE>
 ---                    MF0:/L
 ---                    <NEXT PAGE>             Display directory
```

If you are using a 1720A, look on the directory for the next file to be copied, and write it down. Then, if for example the next file is **FUP.CIL**, continue the procedure as follows:

```
 ---                    <PAGE MODE>             Make sure it's off
ED0:/Z                  MM0:/Z                  Clear memory
ED0:=MF0:FUP.CIL/W      MM0:=MF0:FUP.CIL/W      Continue copying
```

Continue this procedure until there are no more files to copy. If you using a 1720A, you do not need file **OPER/.BAL** or any of the files that follow it in the directory.

Use a 1722A if you need the copy to work on either controller. A copy made by a 1720A will not work on a 1722A.

Copying the 5200.DAT File

When you have your 5200A Calibrator (and 5205A or 5215A Amplifier) characterized with a Fluke 5200A-90x service, you get a table of corrected voltage settings in both printed and compatible disk-file form. To use this disk file with 5200A-800 software, you will need to copy it onto the working-copy disk you just made.

Use the same FUP **/B** procedure that you would to copy any other binary format file. Use this procedure, except that you can skip the **ED0:/C-1** command if your 1722A has expansion memory installed:

```
1722A                   1720A                   Comments

        (Insert 5200A-800 disk)
<RESTART>               <RESTART>               Start up the software
<CTRL>C                 <CTRL>C                 Stop the software
 ---                    EXIT                    Exit BASIC (1720A only)
FUP                     FUP                     File Utility Program
ED0:/C-1                 ---                    Configure main memory
ED0:=MF0:5200.DAT/B     MM0:=MF0:5200.DAT/B     Copy file from disk
        (Insert working disk)
```

MF0:=ED0:5200.DAT/B MF0:=MM0:5200.DAT/B Copy file onto disk

Changing IEEE-488 Bus Address

As supplied, 5200A-800 operating software expects the 5200A calibrator to be set for Bus Address 1. Bus addressing for calibrator operating software uses the variable **IA%** (Instrument Address) to identify the 5200A Bus Address. This variable is assigned early in the **OPER** program, and can be easily changed.

Following are step-by-step instructions to change the 5200A Bus Address. Where they are different, 1720A instructions are shown in [brackets].

1. Insert the 5200A-800 disk and press **RESTART**.
2. When the Start-Up screen appears, type **<CTRL>C**
3. Type **BASIC** [skip this step for 1720A].
4. Type **OLD "MF0:OPER_.BAL"** [skip this step for 1720A].
5. Type **EDIT**
6. Look about 8 lines down from the top for the line

   IA%=1%

   Use the arrow keys to move the cursor to the **1**. Press **DEL CHAR** and replace the number with the Bus Address that you would like to use.
7. Type **<CTRL>C**
8. Remove the write-protect tab from the side of the disk cover and replace the disk in the disk drive. Then type **SAVEL "OPER_"**. [For 1720A, type **SAVEL "OPER"**]. Replace the write-protect tab on the disk.

If you will be using 5200A-800 software to generate compatible tables of correction factors, refer also to the instructions in Section 4 for changing Bus addressing of calibration software.

SOFTWARE STRUCTURE

5200A-800 software is supplied in a form that allows it to run on either a 1722A or 1720A Instrument Controller, even though a 1720A can access only one side of the disk. This is accomplished in the following way:

- The disk is formatted across both sides in a continuous format. (Normal 1722A disk format alternates sides to reduce head movement during file access.)
- All 1720A software is placed on the disk first. This allows the 1720A to have access to it.

Program files are in lexical form. This allows faster operation, since some operations chain to other programs. However this requires separate 1722A and 1720A program files.

1722A and 1720A system software use different file names. This allows each controller to recognize its own system software. Here is a list of the files on your 5200A-800 disk:

File Name	Description
COMMND.SYS	1720A start-up command file
STRTUP.CMD	1722A start-up command file
STRT1 .CMD	1722A start-up command file (E-Disk allocation)
STRT2 .CMD	1722A start-up command file
5200 .DAT	Table of correction factors
FDOS .SYS	1720A system software
CONMON.SYS	1720A console monitor
BASIC .CIL	1720A BASIC interpreter
FUP .CIL	1720A File Utility Program
TIME .CIL	1720A Time-set utility
OPER .BAL	5200A-800 operating program, 1720A version
CALA .BAL	5200A-800 calibration program A, 1720A version
CALB .BAL	5200A-800 calibration program B, 1720A version
OPER_ .BAL	5200A-800 operating program, 1722A version
CALA_ .BAL	5200A-800 calibration program A, 1722A version
CALB_ .BAL	5200A-800 calibration program B, 1722A version
FDOS2 .SYS	1722A system software
MACRO .SYS	1722A system software
BASIC .FD2	1722A BASIC interpreter
FUP .FD2	1722A File Utility Program
TIME .FD2	1722A Time-set utility

Notice that 1722A versions of 5200A-800 programs are identified by a "_" after the file name. This is not a legitimate file name character for a 1720A. If you look at this directory with a 1720A, you will see "/" instead (eg: OPER/.BAL).

The program files on your 5200A-800 disk have had comments stripped and are in lexical form. This allows them to load faster and to fit onto the disk. In some cases they are the result of merging two files.

INSTRUMENT SETUP

Controller Display Alignment

1722A and 1720A instrument controllers use a touch-sensitive display overlay that is independent of the location of displayed characters. Adjustments within the controller video section affect character location. If the controller display is not properly aligned, operation of an application program such as the 5200A-800 can be difficult. This is particularly true for the data-entry keypad screen which allocates one sense location for each number.

You can use the data-entry keypad to do a quick check of alignment. Select **Demo Mode** from the Start-Up screen to get the keypad. If you look

closely at the display overlay, you will see horizontal and vertical lines. These are isolation lines between conductive bands. (You can see them easier in low light with a flashlight held at an angle.) The horizontal lines should line up with the horizontal display lines of the keypad. The vertical lines should be about a half-character width to the left of the horizontal display lines of the keypad.

If you decide that your controller display alignment requires adjustment, refer to your controller service manual or call your nearest Fluke Technical Service Center for advice.

Instrument Setup

For normal operation, connect the equipment as follows:

1. Make sure each instrument is turned off.

2. Connect an IEEE-488 cable from Port 0 on the controller to the IEEE-488 connector on the 5200A.

3. Set the IEEE-488 Address Switch on the 5200A (located just below the IEEE-488 connector) to 1. Do this by setting the top switch segment (A1) to 1 (left) and setting the remaining switch segments to 0 (right).

4. If a 5205A or 5215A Amplifier is included, connect it to J32 on the bottom rear panel of the 5200A using the cable supplied with the amplifier (Fluke Part Number 341560). Consult the amplifier manual first before making this connection if you are unfamiliar with the amplifier.

INTRODUCTION

When a 5200A Calibrator and 5205A or 5215A Amplifier is characterized by Fluke with a 5200A-90x option, a table of corrected voltages is supplied in both printed and 5200A-800 compatible disk-file form.

This section tells you how to manually use a printed **5200A-90x** table of corrected voltages to enhance the accuracy of a 5200A AC Calibrator and 5205A or 5215A Amplifier. For the points on the table, you simply substitute the table value. For other points, you must interpolate between points. Worked-out examples are included.

SAMPLE TABLE OF CORRECTED VOLTAGES

Table 3-1 is a sample table of corrected voltages developed for a calibrator at Fluke. These values will be used for example calculations.

FREQ (Hz)	VOLTAGE 50 mV	100 mV	0.5 V	1.0 V	3.0 V
50	49.9998*	99.9976*	0.499998	0.999976	2.99989
100	50.0000*	100.0013*	0.500000	1.000013	3.00002
200	50.0002*	100.0015*	0.500002*	1.000015	3.00003
1k	50.0022*	100.0023*	0.500022	1.000023	3.00013
2k	50.0023*	100.0030*	0.500023*	1.000030	3.00024
10k	50.0026*	100.0057*	0.500026	1.000057	3.00026
20k	50.0033*	100.0060*	0.500030*	1.000060	3.00023*
50k	50.0040*	100.0112*	0.500040	1.000112	3.00016
100k	50.0020*	100.0263*	0.500121	1.000263	2.99991
	10 V	30 V	100 V	300 V	1000 V
50	9.99970	29.9997	99.9992	299.995	999.980
100	10.00007	30.0009	100.0031	300.010	1000.020
200	10.00010	30.0010*	100.0044	300.011*	1000.023
1k	10.00025	30.0018	100.0053	300.022	1000.047
2k	10.00073	30.0017*	100.0045	300.023*	1000.050
10k	10.00068	30.0016	100.0032	300.029	1000.067
20k	10.00063	30.0008*	100.0014	300.029*	1000.138
50k	10.00010	29.9984	99.9980	300.030	1000.330
100k	9.99907	29.9946	99.9865		

Table 3-1. Sample 5200A-90x Table of Corrected Voltages

Values identified with an asterick are not directly characterized. For millivolt levels, these values are derived from 0.5V and 1.0V corrections respectively by multiplying by 0.1. Other indirect values are derived by interpolation from the frequencies above and below.

DIRECT CORRECTION

For the points listed in the table of corrected voltages, these corrections may be used directly. The calibrator is simply set to the value in the table.

For example, the calibrator that generated Table 3-1 can be set to 1V at 1kHz within the uncertainty given in the specifications in Section 1 by setting it to 1.000023 V.

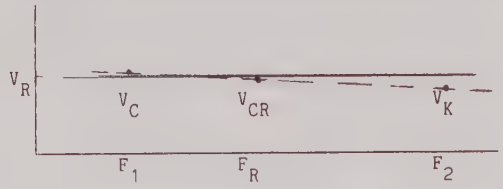
INTERPOLATED CORRECTION

Linear interpolation is used. The choice of linear interpolation was based on the design of the 5200A as well as its performance history. This method of interpolation has been demonstrated valid by verification of measured data from a cross section of new and existing 5200A calibrators.

Three examples are worked out in this section. The first interpolates between two characterized frequencies at a characterized voltage. A second example interpolates between two characterized voltages at a characterized frequency. The third example interpolates both voltage and frequency for a point that is between both voltage and frequency points on the table.

Example 1: Interpolation Between Frequency Points

Figure 3-1 illustrates interpolation between frequency points. The voltage errors at frequencies F_1 and F_2 are known because they are in the table of corrected voltages. In this example we want to use the calibrator at voltage V_R which is a characterized voltage, and at frequency F_R, which is not a characterized frequency and is between F_1 and F_2



F_1 = Next lower characterized frequency

F_2 = Next higher characterized frequency

F_R = Requested frequency

V_R = Requested voltage

V_C = Corrected voltage at F_1 (from Table 3-1)

V_K = Corrected voltage at F_2 (from Table 3-1)

V_{CR} = Corrected voltage for V_R,F_R (unknown)

Figure 3-1. Example 1

To calculate the voltage correction at F_R, this equation is used:

$$V_{CR} = V_C + (V_K - V_C) \left(\frac{F_R - F_1}{F_2 - F_1}\right)$$

In this example we will calculate a corrected voltage setting for **10V** at **80 kHz**, using the calibrator that generated Table 3-1.

For our selected values, the known variables are:

F_1 = 50k Hz

F_2 = 100k Hz

F_R = 80k Hz

V_C = 10.00010V

V_K = 9.99907V

The calculation of V_{CR} proceeds like this:

$$V_{CR} = 10.00010V + (9.99907V - 10.00010V)\left(\frac{80\ kHz - 50\ kHz}{100\ kHz - 50\ kHz}\right)$$

$$= 10.00010V + (-0.00103V)\left(\frac{30}{50}\right)$$

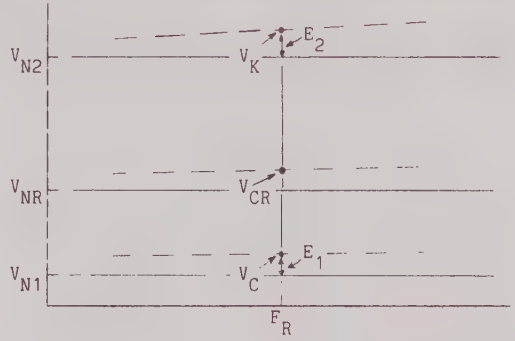
$$= 10.00010V - 0.00062V$$

$$= 9.99948V$$

Therefore, to more closely approach 10V at 80 kHz, we need to set this 5200A to 9.99948V.

Example 2: Interpolation Between Voltage Points

Figure 3-2 illustrates interpolation between voltage points. The voltage errors at voltages V_{N1} and V_{N2} are known from the 5200A-90x table. In this example we want to use the calibrator at voltage V_{NR}, which is between V_{N1} and V_{N2}. All these voltages are at a frequency which is on the 5200A-90x table.



V_{N1} = Nominal value of next lower characterized voltage

V_{N2} = Nominal value of next higher characterized voltage

V_{NR} = Nominal requested voltage

F_R = Requested frequency

V_C = Corrected value of next lower characterized voltage

V_K = Corrected value of next higher characterized voltage

E_1 = Error correction at V_{N1} $(= V_C - V_{N1})$

E_2 = Error correction at V_{N2} $(= V_K - V_{N2})$

V_{CR} = Corrected voltage for V_{NR} (unknown)

Figure 3-2. Example 2

This calculation of V_{CR} proceeds as follows:

To calculate the voltage correction at V_{NR}, F_R, this equation is used:

$$V_{CR} = V_{NR} + E_1 + (E_2 - E_1)\left(\frac{V_{NR} - V_{N1}}{V_{N2} - V_{N1}}\right)$$

In this example we will calculate a corrected voltage setting for **5V** at **1 kHz**, using the calibrator that generated Table 3-1.

For our selected values, the known variables are:

$$V_{N1} = 3V$$

$$V_{N2} = 10V$$

$$V_{NR} = 5V$$

$$V_C = 3.00013V$$

$$V_K = 10.00025V$$

$$E_1 = V_C - V_{N1} = 3.00013V - 3V = 0.00013V$$

$$E_2 = V_K - V_{N2} = 10.00025V - 10V = 0.00025V$$

This calculation of V_{CR} proceeds as follows:

$$V_{CR} = 5V + 0.00013V + (0.00025V - 0.00013V)\left(\frac{5V - 3V}{10V - 3V}\right)$$

$$= 5.00013V + 0.00012V\left(\frac{2}{7}\right)$$

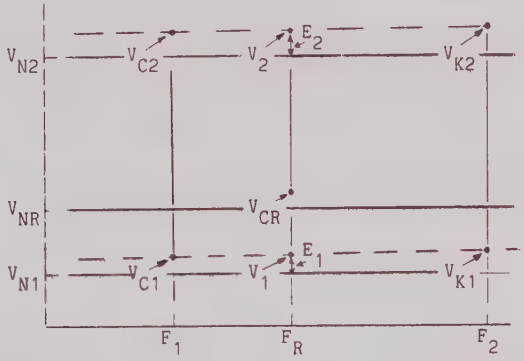
$$= 5.00013V + 0.00003V$$

$$= 5.00016V$$

Therefore, to more closely approach 5V at 1 kHz, we need to set this 5200A to 5.00016V.

Example 3: Interpolation Between Voltage and Frequency Points

Figure 3-3 illustrates interpolation between voltage and frequency points. In this example we want to use the calibrator at frequency F_R (requested frequency), which is somewhere between F_1 and F_2, and voltage V_{NR} (nominal requested voltage), which is between V_{N1} and V_{N2}. Neither F_R nor V_{NR} are on the 5200A-90x table.



F_1 = Next lower characterized frequency

F_2 = Next higher characterized frequency

F_R = Requested frequency

V_{N1} = Nominal value of next lower characterized voltage

V_{N2} = Nominal value of next higher characterized voltage

V_{NR} = Nominal requested voltage

V_{C1} = Lower corrected voltage at F_1

V_{C2} = Higher corrected voltage at F_1

V_{K1} = Lower corrected voltage at F_2

V_{K2} = Higher corrected voltage at F_2

V_1 = Lower corrected voltage at F_R

V_2 = Higher corrected voltage at F_R

E_1 = Error correction at V_{N1}, F_R (= $V_1 - V_{N1}$)

E_2 = Error correction at V_{N2}, F_R (= $V_2 - V_{N2}$)

V_{CR} = Corrected voltage at V_{NR}, F_R (unknown)

Figure 3-3. Example 3

To calculate the corrected voltage V_{CR}:

$$V_1 = V_{C1} + (V_{K1} - V_{C1}) \left(\frac{F_R - F_1}{F_2 - F_1}\right)$$

(Similar to Example 1)

$$V_2 = V_{C2} + (V_{K2} - V_{C2}) \left(\frac{F_R - F_1}{F_2 - F_1}\right)$$

(Similar to Example 1)

$$V_{CR} = V_{NR} + E_1 + (E_2 - E_1) \left(\frac{V_{NR} - V_{N1}}{V_{N2} - V_{N1}}\right)$$

(Similar to Example 2)

For this example we will calculate a corrected voltage for **5V** at **5 kHz**, using the calibrator that generated Table 3-1.

For our selected values, the known variables are:

F_1 = 2k Hz

F_2 = 10k Hz

F_R = 5k Hz

V_{C1} = 3.00024V

V_{C2} = 10.00073V

V_{K1} = 3.00026V

V_{K2} = 10.00068V

V_{NR} = 5V

The calculation to solve for V_{CR} proceeds like this:

$$V_1 = 3.00024V + (3.00026V - 3.00024V) \left(\frac{5k\ Hz - 2k\ Hz}{10k\ Hz - 2k\ Hz}\right)$$

$$= 3.00024V + 0.00002V \left(\frac{3}{8}\right)$$

$$= 3.00024V + 0.00001V$$

$$= 3.00025V$$

$$V_2 = 10.00073V + (10.00068V - 10.00073V) \left(\frac{5k\ Hz - 2k\ Hz}{10k\ Hz - 2k\ Hz}\right)$$

$$= 10.00073V + (-0.00005)V \left(\frac{3}{8}\right)$$

$$= 10.00073V - 0.00002V$$

$$= 10.00071V$$

$$E_1 = V_1 - V_{N1}$$

$$= 3.00025V - 3V$$

$$= 0.00025V$$

$$E_2 = V_2 - V_{N2}$$

$$= 10.00071V - 10V$$

$$= 0.00071V$$

$$V_{CR} = 5V + 0.00025V + (0.00071V - 0.00025V) \left(\frac{5V - 3V}{10V - 3V}\right)$$

$$= 5V + 0.00025V + 0.00046 \left(\frac{2}{7}\right)$$

$$= 5.00025V + .00013V$$

$$= 5.00038V$$

Therefore, to more closely approach 5V at 5 kHz, we need to set this 5200A to 5.00038V.

Section 4
Characterization Procedure

INTRODUCTION

Model 5200A-800 Operation and Calibration Software includes programs that allow you to develop your own table of corrected voltages for a 5200A AC Calibrator and a 5205A or 5215A Precision Amplifier. This section describes procedures that use those programs. If you will be using Fluke characterization services (see Section 1), you will not need the information in this section.

WARNING

HIGH VOLTAGE
is used in the operation of this equipment.

DEATH ON CONTACT
may result if you do not understand and follow safety procedures.

Note

While this procedure is identical to that used by Fluke to achieve the performance specifications given in Section 1, that performance relies on established metrology laboratory conditions, and on skills that are beyond the scope of this manual. This procedure does not ensure characterization integrity, nor does it provide checks for valid characterized values. You are responsible for deriving valid constants and ensuring correct data entry.

The characterization procedure precisely measures the output of the 5200A calibrator at 46 voltage/frequency points, and produces a list of corrected voltage settings. An additional 13 points are measured when a 5205A or 5215A amplifier is included.

REQUIRED EQUIPMENT

The procedure relies on the equipment listed in Table 4-1. The calibration program (on the 5200A-800 disk) runs on a Fluke 1722A or 1720A Instrument Controller. It provides procedure-step prompts for interconnections and 540B settings, control of the 5440B or 5440A, and recording and printing of the characterization table.

Instrument Controller:	Fluke 1722A or 1720A
Thermal Transfer Standard:	Fluke 540B, characterized
DC Source:	Fluke 5440B or 5440A
Cables:	Belden 9271 low capacitance 4 each 30 cm lengths, with spade lugs
Connector:	Pomona #1699 or #1698 Binding post to UHF

Table 4-1. Required Equipment

The 540B must be accompanied by a valid Report of Calibration from the Fluke Primary Standards Laboratory, or otherwise characterized at the points and the uncertainties listed in Table 4-2.

Voltage	Uncertainty (± Percent)		
	20 kHz	50 kHz	100 kHz
0.5	.005	.01	.02
1	.005	.01	.02
3	.005	.01	.02
10	.005	.01	.02
30	.005	.01	.02
100	.005	.01	.02
300	.005	.05	*
1000	.005	.05	*

Table 4-2. Required 540B Characterization Points and Uncertainties
(* beyond volt-hertz limit)

GETTING FAMILIAR

The characterization program is menu-driven to guide you through the process. Most commands are entered through the touch-sensitive display of the controller.

This familiarization exercise uses **Demo Mode**. You do not need to have instruments connected to the 1722A or 1720A controller.

To enter the characterization program, start up the 5200A-800 disk as described in Section 2, and touch-select

Characterize
5200A/52x5A

on the start-up display.

The response will be:

```
VERIFY 5200A SERIAL NUMBER

S/N :0000000

[YES]          [NO]
```

To change the stored serial number, touch-select: **NO**, and it will respond with

```
ENTER 5200A SERIAL NUMBER

   ?
```

Use the keyboard to enter a 7-digit number, and it will return to the **VERIFY 5200A SERIAL NUMBER** screen, with the new serial number displayed.

If the serial number is correct, touch-select **YES**, and it will respond with:

```
DO YOU HAVE A 5205A OR 5215A
   VOLTAGE AMP CONNECTED?

[YES]          [NO]
```

If you select **NO**, it will respond with the Main Menu below.

If you select **YES**, it will again ask you to verify or enter a serial number. After verifying or entering the serial number, it responds with the Main Menu:

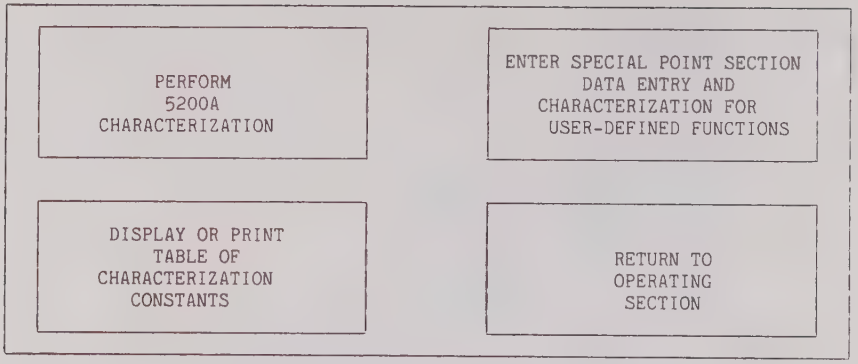


Figure 4-1. Main Calibration Menu

From the Main Menu you can:

- Proceed to standard-point characterization.
- Enter the special-point characterization program.
- Display the characterization table as it currently exists.
- Leave the characterization program (return to operation).

Touch-select **RETURN TO OPERATING SECTION**. The response allows you touch-select **(1)** to return to the start-up display of Figure 2-1, or to touch-select **(2)** to change your decision and return to the **Main Menu** display of Figure 4-1. Touch-select **(2)**.

From the Main Menu, touch-select **PERFORM 5200A CHARACTERIZATION**. The software responds with a message to refer to this manual for set-up instructions, and to make sure the calibrators have warmed up. Ignore this for now, and touch the screen.

The next message instruct you to set IEEE-488 Bus addresses, set up the 5200A front panel, and connect an IEEE-488 Bus cable to the controller.

Note

If you would like to change the IEEE-488 Bus addressing in the calibrating portion of the software, refer to the end of this section for instructions.

Touch-select the lower-right of this diplay in the touch-sense area labelled **DEMO MODE**. In Demo Mode, IEEE-488 Bus commands are suppressed. This allows you to try out the software without instruments connected to the controller.

You now have a menu with three choices:

(1) ENTER OR CHANGE AC/DC
DIFFERENCE CONSTANTS FOR 540B

(2) DISPLAY TABLE OF AC/DC
DIFFERENCE CONSTANTS

(3) CONSTANTS CORRECT
CONTINUE CHARACTERIZATION

You are asked at this point to verify or correctly enter a table of AC/DC difference constants for the 540B Thermal Transfer Standard that you will be using. These correction factors are used in the final calculations of 5200A corrected voltages.

Touch-select **(2)** to display the table of 540B AC/DC difference constants currently stored on the disk. The 10 kHz constants are a function of the 20 kHz constants, calculated by software. Touch the screen again.

This time touch-select **(3)**.

You now have a menu with two choices:

(1) PROCEED WITH COMPLETE 5200A
CHARACTERIZATION IN SEQUENCE
(0.5 TO 100V, 50 HZ TO 100 HZ)

(2) SELECT SPECIFIC VOLTAGE AND
FREQUENCY POINT (MUST BE
CHARACTERIZATION POINT)

At this point you can choose to develop a complete 5200A-90x compatible characterization table in sequence, or to simply re-characterize one of the points on that standard table.

Touch-select **(1)**.

The controller next produces the Characterization Point Display shown in Figure 4-5. You can choose to characterize this point, go to the next point in the sequence, display the table of 5200A characterization constants, or terminate.

Touch-select **CHARACTERIZE**.

The first time through this sequence, the software interrupts at this point with instructions for 540B settings. **Do not change any 540B settings at this time.** Touch the display to continue.

The controller display responds with a message to allow 30 minutes for 540B stabilization. Time remaining is displayed for convenience. You can touch the screen at any time to continue.

The next display instructs you to wait 10 seconds, and null the 540B galvanometer. **Do not change any 540B settings at this time.** Touch the display to continue.

The controller momentarily displays **SET "GALV" SWITCH TO "OPEN"**.

The controller then shows the AC/DC Transfer Control Display, with these five options:

DC NULL

AC NULL

CHANGE DC POLARITY

ENTER CHAR. POINT

TERMINATE

Touch-select **TERMINATE**. This returns you to the Characterization Point Display.

Figure 4-2 is a flowchart of the characterization program. You will find it useful for finding your way through the characterization procedure.

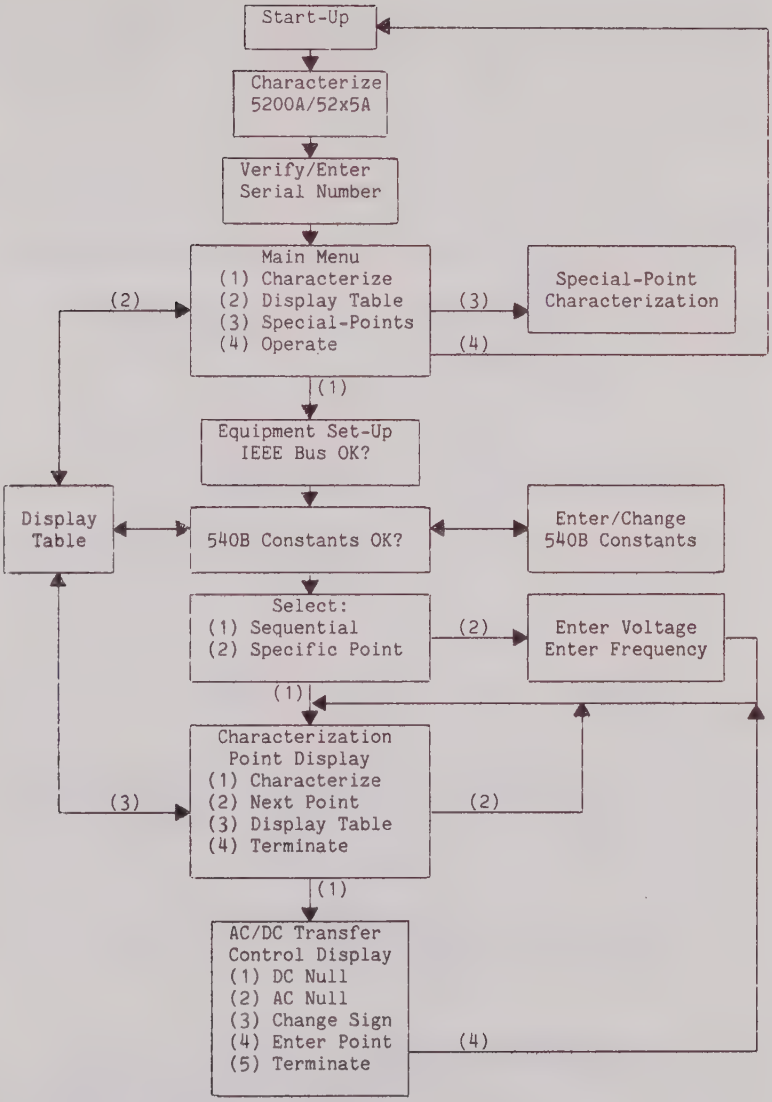


Figure 4-2. Characterization Program Flowchart

INITIAL PREPARATION

This characterization must be performed in a thermally stable environment, within the temperature range of 23°C ± 1°C. The 5200A (and 52x5A) must be allowed to thermally stabilize at least two hours, power ON, in the controlled environment.

Before connecting your instruments, verify each of the following:

1. The 5200A to be characterized has Option 5200A-05 (IEEE-488 interface) installed.

2. The 5200A has passed the following verification tests in the 5200A Instruction Manual:

4-30	Output Accuracy Test - Voltage Ranges
4-40	Frequency Output Test
4-43	Distortion Tests
4-50	Line Regulation Test

3. The 540B Thermal Transfer Standard has a valid Certification Document that includes a table of AC/DC difference constants for all the points and within the uncertainties listed in Table 4-2.

4. The 5440B or 5440A is within its calibration cycle, and has performed its analog self-tests and its internal calibration within the last 24 hours. (Refer to the 5440B or 5440A Service Manual for instructions.)

5. The 540B Thermal Transfer Standard has passed the operating checks that follow.

540B OPERATING CHECKS

The 540B Thermal Transfer Standard must be functionally tested immediately prior to beginning this characterization procedure. Failure to verify 540B operation can lead to errors in characterization accuracy. Also, be sure to verify valid calibration dates on the 540B and its accompanying Report of Calibration.

Battery Check

Set the **POWER** switch to **REFERENCE, GALV** and to **SEARCH**. The **PERCENT INPUT** meter must read above the lower limit of the **BAT** band on the meter scale in all three battery check positions.

Range Check

Set 540B **RANGE** to 10 Volts and **MODE to OFF**. Apply 10 V DC from 5440B or 5440A calibrator to the 540B **DC INPUT** terminals. Set 540B **MODE** to **DC SEARCH**. Verify approximately 100% indication on the 540B **PERCENT INPUT** meter.

Switch Contact Check

Set the 5440B or 5440A calibrator to **STANDBY**. Rotate all 540B switches and **REFERENCE ADJUST** controls vigorously at least 15 times, through all ranges and against the stops.

Null Check

Re-apply 10 V DC from the 5440B or 5440A calibrator. Set 540B **MODE** to **DC TRANSFER**. Obtain a null on the galvanometer.

Galvanometer Control Checks

Verify good contact on the galvanometer **SENSITIVITY** switch and **REFERENCE ADJUST** controls by lightly tapping on them.

After giving the 540B Thermal Element several minutes to stabilize, verify that the **FINE** REFERENCE ADJUST control gives a stable and linear response on the galvanometer.

Depress **SENSITIVITY TEST** to the 0.01% position and note a positive galvanometer deflection of approximately 7 small divisions.

Set **SENSITIVITY** to **MED** and verify that the **MEDIUM** REFERENCE ADJUST control gives a stable and linear response on the galvanometer.

Depress **SENSITIVITY TEST** to the 0.1% position and verify positive galvanometer deflection. Set **SENSITIVITY** to **HIGH**. Adjust for a null on the galvanometer.

Set the **GALV** switch to **OPEN**. Rotate the **MODE** switch several times rapidly between **DC TRANSFER** and **AC TRANSFER**.

Set the **GALV** switch to **MOMENTARY** and verify that the null repeats to within one small division. (It is very important that the 540B pass this test.)

With a good null on the galvanometer, set the **GALV** switch to **OPEN** and press **CHNG SIGN** on the 5440B or 5440A calibrator. Set the **GALV** switch to **MOMENTARY** and verify a total galvanometer deflection of less than 0.01%.

Set the **GALV** switch to **OPEN** and press **CHNG SIGN** on the 5440B or 5440A calibrator. Check that galvanometer deflection is within one small division from the original DC polarity. (Do not change the REFERENCE ADJUST controls. The null must repeat from the previous settings.)

Set the 5440B or 5540A to **STANDBY**, 540B **MODE** and **POWER** to **OFF**.

Notes

If the 540B fails any of these functional tests, appropriate servicing must be performed. Disturbing A54 components can affect calibration corrections. Any servicing of the A54 range switch contacts must be performed immediately prior to 540B calibration.

If you will be servicing your own 540B, ask your local Fluke Technical Service Center for a copy of Fluke Service

Bulletin C0064 **Fluke Instrument Switches.** It provides recommended cleaning and lubricating procedures for switches used in Fluke instruments.

EQUIPMENT SETUP

WARNING

THIS PROCEDURE INVOLVES CONNECTION AND OPERATION OF EQUIPMENT GENERATING LETHAL VOLTAGES. DO NOT ATTEMPT ANY OF THESE PROCEDURES UNLESS YOU THOROUGHLY UNDERSTAND THEM AND HAVE BEEN TRAINED IN AND ARE FOLLOWING ADEQUATE SAFETY PROCEDURES.

Connect the equipment as shown in Figure 4-3. If you are characterizing a 5205A or 5215A amplifier, refer to Figure 4-4 when the program prompts for amplifier connections.

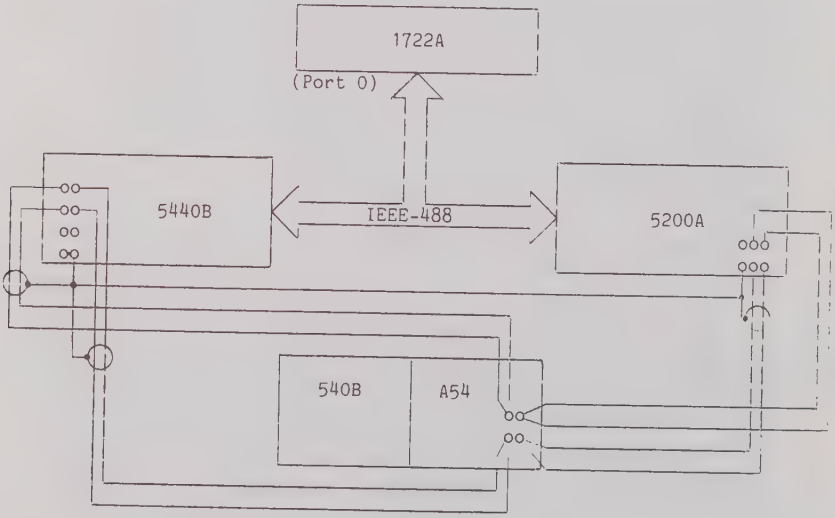


Figure 4-3. Equipment Setup, 5200A

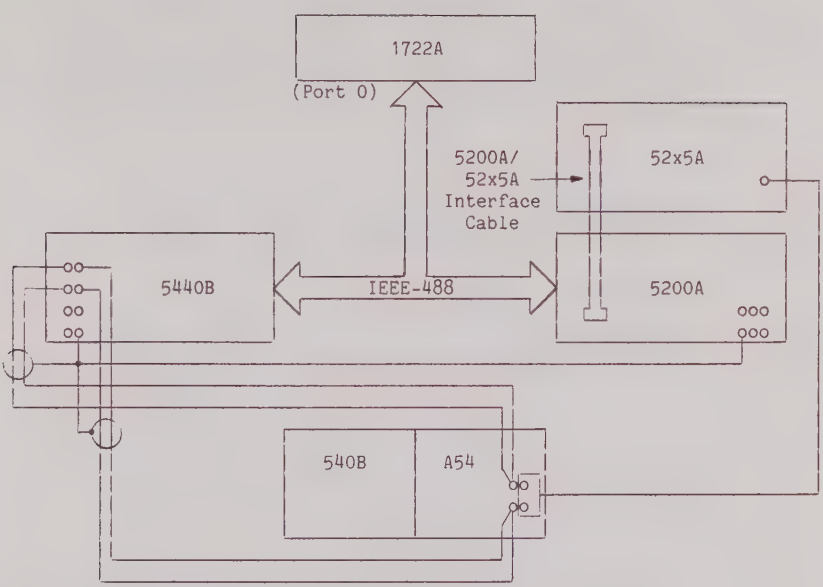


Figure 4-4. Equipment Setup, 5205A or 5215A

Set the equipment controls as follows:

1. Set the 5200A to **POWER-ON, CONTROL-REM.**

2. Set the 540B **POWER** switch **ON.** Select **MODE OFF.**

Start up the controller as follows:

1. With the controller ON, insert the 5200A-800 floppy disk, and press RESTART.

2. When the display illustrated in Figure 2-1 appears, touch-select **Characterize 5200A/52x5A.**

3. Verify or enter the serial number of the 5200A. Touch-select **YES** or **NO** to the prompt, **DO YOU HAVE A 5205A OR 5215A VOLTAGE AMP CONNECTED?** and enter the amplifier's serial number if used.

4. The Main Menu, shown in Figure 4-1, appears. Select **PERFORM 5200A CHARACTERIZATION.** This calls up a message referring you to this manual for setup instructions. Touch the display.

5. The display next instructs you to set bus addresses on the 5200A and 5440B. Set these bus addresses. Refer to the instruction manuals of each instrument for address switch locations if necessary. If you

would like to modify the program for a different address, refer to the the instruction at the end of this Section.

6. Verify correct equipment setup, and correct IEEE Bus addresses. The program will not operate (except in Demo Mode) unless the 5440B and 5200A addresses are correct and the 5200A is set to REM.

7. Touch the display. The menu shown below will appear:

   (1) ENTER OR CHANGE AC/DC
   DIFFERENCE CONSTANTS FOR 540B

   (2) DISPLAY TABLE OF AC/DC
   DIFFERENCE CONSTANTS

   (3) CONSTANTS CORRECT
   CONTINUE CHARACTERIZATION

8. Leave the equipment on and allow it to warm up for two hours before characterizing. Leave the controller running. The next instructions begin with the program at the menu shown in the last step.

ENTERING 540B CHARACTERIZATION CONSTANTS

AC/DC Difference Constants for the 540B Thermal Transfer Standard must be entered into the program before 5200A characterization can begin. These constants are listed on the 540B/A54 Certification Document from the Fluke Primary Standards Lab. Once entered, these constants are stored on disk. They need not be re-entered unless they change. Use this procedure to enter the constants:

1. Start from this menu, from the end of the equipment setup procedure:

   (1) ENTER OR CHANGE AC/DC
   DIFFERENCE CONSTANTS FOR 540B

   (2) DISPLAY TABLE OF AC/DC
   DIFFERENCE CONSTANTS

   (3) CONSTANTS CORRECT
   CONTINUE CHARACTERIZATION

   Touch select (1).

2. Now sequentially enter the AC/DC difference constants from the 540B/A54 Certification Document, beginning with 0.5V at 20 kHz. These will replace whatever is already recorded on the disk. Enter all the values listed in Table 4-2 following the instructions from the prompts on the controller display.

   When an AC/DC constant is entered or changed, the display is updated to allow the entry to be verified. Press the RETURN key to store the entry and sequence to the next voltage. After you have entered the

100V constant (or 1000V when using a 5205A or 5215A), the display sequences to next frequency. The levels 300V and 1000V at 100 kHz are beyond the volt-hertz limit of a characterized 540B, so they are omitted. After you enter the 100V/100 Hz constant, program control is returned to the display, and the menu from step 1 is displayed.

Note

The AC/DC constants for 10 kHz are a function of the 20 kHz constants. They are calculated by the program after all other constants are entered. Be sure to enter all the AC/DC constants the program requests, even if the values are zero.

3. To see the table of 540B constants as stored in the program, select **(2) DISPLAY TABLE OF AC/DC DIFFERENCE CONSTANTS** from the menu. This table is automatically displayed after the last data entry. Check the table to verify all constants and polarities before continuing.

Note

The program does not check 540B status or the validity of characterization values entered. Carefully review the table of 540B AC/DC constants at the end of the sequence. Verify any values that deviate from adjacent values or are not within specifications.

4. From the menu, select **(3) CONSTANTS CORRECT CONTINUE CHARACTERIZATION.** This calls up the following menu:

(1) PROCEED WITH COMPLETE 5200A CHARACTERIZATION IN SEQUENCE (0.5 TO 100V, 50 HZ TO 100 HZ)

(2) SELECT SPECIFIC VOLTAGE AND FREQUENCY POINT (MUST BE CHARACTERIZATION POINT)

5. From this point you can choose **(1)** for sequential characterization of all standard characterization points, or **(2)** for specific-point characterization. This is useful for leaving the rest of the points the way they are currently, while characterized only a certain point. Later in the instructions, at **Sequential Characterization**, and **Specific-Point Characterization**, you will begin from this branching point.

THE CHARACTERIZATION PROCEDURE

This section includes step-by-step explanations of the instructions and choices presented by the characterization program display. To best understand the characterization procedure, we suggest you use Demo Mode to make a dry run through the program before attempting to characterize your 5200A. (See **Getting Familiar With the Characterization Program** earlier in this section.) Also, review the 540B Operating Instructions in the 540B

Instruction Manual before operating the 540B. **The 540B galvanometer indicator can easily be damaged by improper use.**

The instructions here begin with Sequential Characterization, then explain how to do Specific-Point Characterization (characterization of standard points, but selected out of sequence, individually). Finally, there are instructions for setting up your own custom points. This is called Special-Point Characterization.

You should have have all equipment running now, have all 540B constants entered into the program, and be at the menu that reads:

> (1) PROCEED WITH COMPLETE 5200A CHARACTERIZATION IN SEQUENCE (0.5 TO 100V, 50 HZ TO 100 HZ)
>
> (2) SELECT SPECIFIC VOLTAGE AND FREQUENCY POINT (MUST BE CHARACTERIZATION POINT)

Sequential Characterization

1. From the menu, select:

   > (1) PROCEED WITH COMPLETE 5200A CHARACTERIZATION IN SEQUENCE (0.5 TO 100V, 50 HZ TO 100 HZ)

2. The program is now at the Characterization-Point Display, shown in Figure 4-6. The voltage and frequency of the characterization point are shown on the display. From here you can skip to the next point, display the whole table and return to this point, terminate the procedure, or characterize this point. To characterize this point, touch select **CHARACTERIZE**.

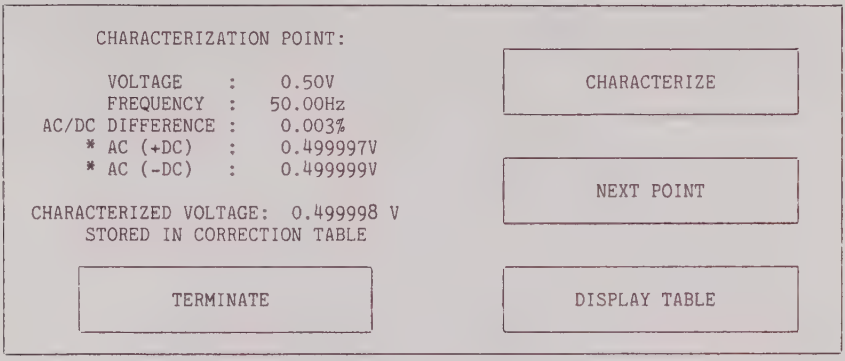


Figure 4-5. Characterization Point Display
* Displayed only after derived

3. Touching **CHARACTERIZE** calls up instructions for setting controls on the 540B. Set these 540B controls as shown:

MODE:	DC TRANSFER
RANGE:	.5
SENSITIVITY:	LOW
GALV:	OPEN

Note

For the first reading, leave the 540B **MODE set to SEARCH.** Verify that the **PERCENT INPUT** meter reading is approximately 100% before setting it to transfer.

4. Touch the display. A 30-minute countdown timer is enabled for 540B Thermal Element stabilization. The **PERCENT INPUT** indicator on the 540B should be at 100% as soon as the timer is enabled. If the indicator is not at 100%, make sure 540B power is on and that the 5200A and 5440B are supplying the correct voltages.

5. After the 30-minute timer expires (or is interrupted by touching the display), the following instructions appear on the display:

WAIT 10 SECONDS THEN ENGAGE "GALV" SWTCH
NULL GALVANOMETER USING "REFERENCE
ADJUST" CONTROLS (COURSE, MEDIUM, FINE)
AND "SENSITIVITY" CONTROL
(LOW, MED, AND HIGH) ON 540B

To accomplish this, first make sure the **SENSITIVITY** switch is set to **LOW.** Set the **GALV** switch to **MOMENTARY** while quickly adjusting the **COARSE**, and then **MEDIUM** controls to null the **GALVANOMETER** needle. Set

the **GALV** switch to **LOCK**. Set **SENSITIVITY** to **MED**. Adjust the **MEDIUM** control and then the **FINE** control to again null the **GALVANOMETER** indicator. Set **SENSITIVITY** to **HIGH**, and again null the **GALVANOMETER** as before with the **FINE** control (and the **MEDIUM** control if necessary).

You do not have to use this exact process for nulling the GALVANOMETER. How you do it is up to you. Just be aware that the GALVANOMETER needle is a delicate mechanism, so be careful to keep the needle within range. Be sure you are familiar with 540B operating instructions in Section II of the 540B Instruction Manual.

After nulling the GALVANOMETER, touch the display. You have just completed **DC NULL**, mentioned in the next steps.

6. New instructions appear briefly that say:

   SET "GALV" SWITCH TO "OPEN"

   Do this. The AC/DC Transfer Control Display as shown in Figure 4-6 is then called up.

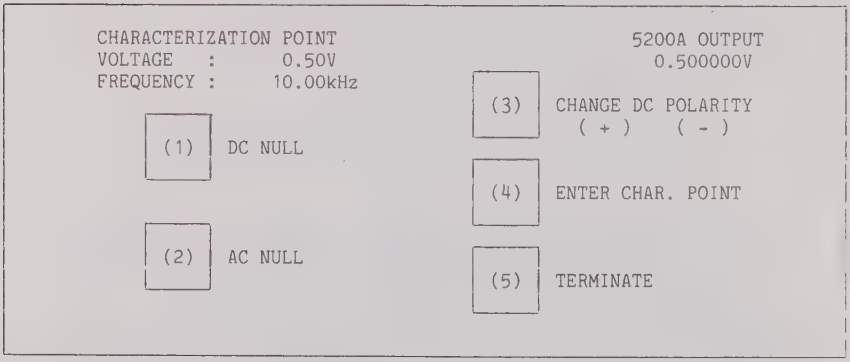


Figure 4-6. AC/DC Transfer Control Display

7. The AC/DC Transfer Control Display provides the main control for the AC and DC nulling of the 540B galvanometer. There are five options on this display. The object at this point is to do option **(2) AC NULL** for both +DC and -DC polarities. AC NULL is similar to DC NULL done in step 4, above, except that the touch sense controls on the controller display are used to null the galvanometer instead of the reference adjust controls on the 540B.

   After each **AC NULL** operation, repeat the **DC NULL** process. When both polarities are done for **AC NULL**, store the characterization constant in the program by touch selecting **(4) ENTER CHAR. POINT**.

   Each of the five menu choices is described briefly below:

(1) DC NULL

Re-energizes the 5440B DC source and prompts you to set the 540B MODE to **DC TRANSFER** and to the appropriate range. The process described in Steps 4 and 5 is DC NULL. Repeat it after each **AC NULL**.

(2) AC NULL

Prompts you to set the 540B MODE to **AC TRANSFER** and to the appropriate range. You are then prompted close the **GALV** switch. (Set it to **LOCK**).

The next touch results in the AC Null Control Display of Figure 4-7. This display provides touch-sense 5200A amplitude control. **HIGH**, **MED**ium, and **LOW** amplitude editing keys control the three least significant digits of 5200A output. Characterization-point nominal voltage and frequency is displayed, and actual 5200A output is displayed in high-intensity.

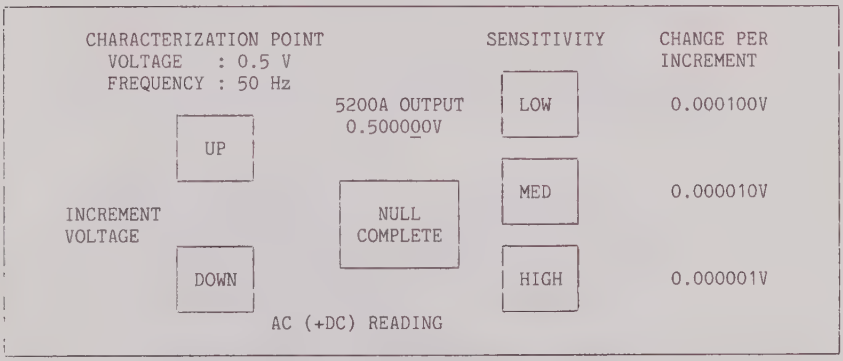


Figure 4-7. AC Null Control Display

Use these controls to null the **GALVANOMETER** needle in a similar manner as Steps 4 and 5 above.

Once **AC NULL** is complete, touch-select **NULL COMPLETE** to return control to the AC/DC Transfer Control Display of Figure 4-6, after a momentary prompt to open the **GALV** switch. **NULL COMPLETE** also stores the 5200A output voltage as a characterization constant. If **AC NULL** is repeated for the same point, this constant is updated.

(3) CHANGE DC POLARITY

Sends a change-sign command to the 5440B DC source. High-intensity identifies the current polarity. After doing **AC NULL**, touch select **(3) CHANGE DC POLARITY** and repeat **AC NULL**. If you do not do **AC NULL** for both DC polarities, you will be prompted to do so when you

touch select (4) ENTER CHAR. POINT.

(4) ENTER CHAR. POINT

Enters AC characterized voltage into memory. This selection prompts you if either the AC(+DC) voltage or the AC(-DC) voltage was not derived, or if the characterized voltage as entered is not within 5200A Basic Instrument Uncertainty Specifications.

This selection returns control to the updated Characterization-Point Display (Figure 4-5), which offers you a choice of repeating the last point or proceeding to the next point.

Note

If the last frequency was 100 kHz, then the next characterization point will require a change in voltage range on the 540B. Change the 540B range at the same time as you touch select to go to the next voltage, to minimize voltage interruption of the thermal element.

(5) TERMINATE

Returns control to Characterization Point Display. A second **TERMINATE** is required to reset the instruments and to exit the program.

Notes

1. Any characterized point null can repeated as many times as necessary, until **ENTER CHAR. POINT** is pressed. If a constant is inadvertently stored, it can be corrected by selecting the specific voltage / frequency point and repeating characterization.

2. Characterized values are the average of the positive AC(+DC) and negative AC(-DC) DC null constants, as well as a function of the AC/DC difference constants. A characterized point will not be accepted for entry until both positive and negative null constants are recorded.

3. When **TERMINATE** is touch selected from the AC/DC Transfer Control Display (Figure 4-6), control returns to the Characterization-Point Display (Figure 4-5). When **TERMINATE** is then touch selected from this display, an instrument reset occurs over the IEEE-488 Bus, and control is returned to the Main Menu. Be sure the 540B **GALVO** switch is open before touch selecting **TERMINATE** and resetting the instruments.

Specific-Point Characterization

Select this option to characterize a subset of the characterization points or to verify a specific point. Also if a non-recoverable error occurs during sequential characterization, you can resume the characterization sequence by entering the last point measured. Using this option, the program automatically resumes sequencing when told to do so. Remember to always observe a 30-minute stabilization period for the 540B Thermal Element whenever power is interrupted.

Specific-Point Characterization can be entered after pressing **TERMINATE** or when restarting the program. To enter this mode, do the following:

1. Select **PERFORM 5200A CHARACTERIZATION** from the Main Menu.

2. After equipment setup and IEEE-488 Address prompts, select **(2) SPECIFIC VOLTAGE AND FREQUENCY POINT.**

3. Enter a voltage and frequency from the points on Table 3-1 when prompted to do so by the display. This calls up the Characterization Point Display (Figure 4-5).

   If either the voltage or frequency entered is not one of the points on Table 3-1, a prompt occurs and both must be re-entered.

4. Characterize the point exactly as in steps 2 through 7 of **Sequential Characterization.**

   After the first point has been characterized and **NEXT POINT** has been selected, you have three options:

   (1) SELECT ANOTHER SPECIFIC VOLTAGE AND FREQUENCY POINT

   (2) PROCEED WITH SEQUENTIAL CHAR. STARTING FROM LAST SELECTED SPECIFIC VOLTAGE/FREQ. POINT

   (3) RETURN TO MENU

   If **(2)** is chosen, the characterization sequence is entered, and there is no further chance to enter a specific point. Choose **(1)** to verify or characterize additional specific points.

Characterization Table Notes

The Table of Characterization Constants, as displayed in the program, is shown in Table 4-3. The table is presented when requested from the Characterization Point Display (Figure 4-5), or from the Main Calibration Menu (Figure 4-1). Before you begin characterization, the table will contain all nominal

values. Then, as each characterization point is derived, its value is automatically entered in the data file. If the point is re-derived, the characterization table constant is updated.

TABLE OF CHARACTERIZATION CONSTANTS STORED IN 5200.DAT

FREQ (Hz)	0.5 V	1.0 V	V O L T A G E 3.0 V	10 V	30 V	100 V	300 V	1000 V
50	0.500000	1.000000	3.00000	10.00000	30.0000	100.0000	300.000	1000.000
100	0.500000	1.000000	3.00000	10.00000	30.0000	100.0000	300.000	1000.000
200	0.500000	1.000000	3.00000	10.00000	30.0000	100.0000	300.000	1000.000
1 k	0.500000	1.000000	3.00000	10.00000	30.0000	100.0000	300.000	1000.000
2 k	0.500000	1.000000	3.00000	10.00000	30.0000	100.0000	300.000	1000.000
10 k	0.500000	1.000000	3.00000	10.00000	30.0000	100.0000	300.000	1000.000
20 k	0.500000	1.000000	3.00000	10.00000	30.0000	100.0000	300.000	1000.000
50 k	0.500000	1.000000	3.00000	10.00000	30.0000	100.0000	300.000	1000.000
100k	0.500000	1.000000	3.00000	10.00000	30.0000	100.0000		

TOUCH SCREEN TO CONTINUE

Table 4-3. Display Table of Characterization Constants

Ten points are not actually measured. Their values are interpolated from adjacent points at the end of the characterization sequence. These values remain nominal until the characterization sequence is completed. The program then interpolates adjacent values and fills them in. Table 3-1 identifies these values with an asterisk (*).

The completed table will contain all non-nominal values, except in the unlikely event that a characterization constant as derived exactly equals the nominal value.

Note

The program does not check 540B status or the validity of characterization values entered. Carefully review the table of characterization data at the end of the sequence. Verify any values that deviate from adjacent values or are not within specifications.

For example, if the corrected value of 1V at 1 kHz is 1.000023V and the corrected value of 1V at 10 kHz is 1.000077V, then a value of 1.000109V for the 1V at 2 kHz range deviates from the range linearity specification and should be verified. A more reasonable value would be 1.000035V. All voltage ranges should exhibit linearity across all frequency ranges except for a non-linear change in amplitude when changing from the 1-kHz range to the 10-kHz range in the 10V-range.

Printing Out the Table

To make a printed copy of the 5200A table of corrected voltages, connect a serial character printer through an RS-232 printer cable to Serial Port 1 (KB1:) of the controller. If you need to configure the controller serial port for data rate, parity, etc., consult the controller manual.

From the Main Calibration Menu (Figure 4-1), touch select:

DISPLAY OR PRINT
TABLE OF CHARACTERIZATION
CONSTANTS

The display will respond with these choices:

(1) DISPLAY TABLE OF
CHARACTERIZATION CONSTANTS

(2) PRINT CHARACTERIZATION
TABLE AT OUTPUT PORT KB1

Touch select **(1)** to get the display in Figure 4-3 above. Touch select **(2)** to get a printed copy similar to Figure 3-1.

If your printer is not producing results, you probably have a mis-match of serial port configuration. Consult your controller manual, of call Fluke Customer Service for assistance.

SPECIAL-POINT CHARACTERIZATION

This option is selected from the Main Menu and actually calls a separate program. Up to fifty non-standard special voltage / frequency points can be entered, changed, edited, or characterized using this option. The data stored can be displayed in a table, and the whole table can be cleared all at once, if desired.

Notes

System limits:

Voltage:	.1 mV to 1199.999V
Frequency:	10 Hz to 1.1999 MHz
Uncertainty:	1.0%.
Characterized Voltage:	10% of Voltage;

For example, minimum/maximum limits at 10V are 9.0V to 11.0V.

540B accuracy degrades rapidly below 0.5V. To characterize voltages below 0.3V, use another method (such as a ratio transformer).

Set up and characterize a special point as follows:

1. Enter the special-point characterization program from the Main Menu

(Figure 4-1) by touch selecting:

ENTER SPECIAL POINT SECTION
DATA ENTRY AND
CHARACTERIZATION FOR
USER-DEFINED POINTS

2. The same setup prompts occur as in sequential characterization, so use the same setup procedure. After setup, the following menu is displayed:

(1) ENTER OR EDIT SPECIAL
CHARACTERIZATION POINTS

(2) ZERO ALL SPECIAL POINTS

(3) DISPLAY TABLE OF SPECIAL
POINTS

3. Touch select **(3)** to look at the table of special points already stored. To clear the table completely, touch select **(2)**.

Touch select **(1)** to set up and characterize a special point.

4. The Special-Point Characterization Menu shown in Figure 4-8 is now displayed with the voltage and frequency for Special Point #1. These values are zero if you have not already programmed Special Point #1.

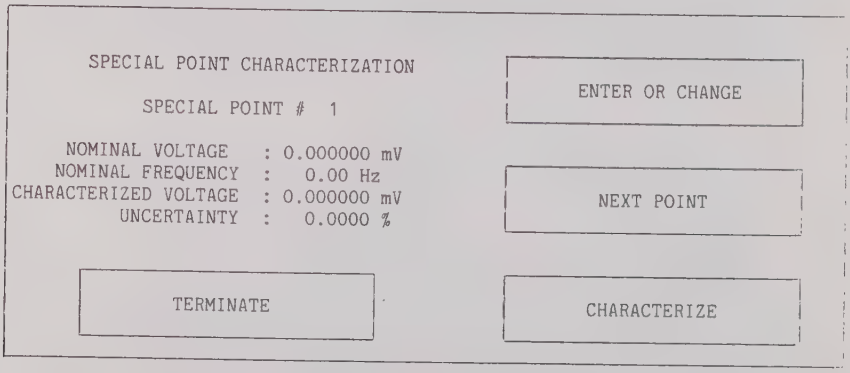


Figure 4-8. Special-Point Characterization Menu

If there are special points programmed, you can step to the one you want to recharacterize or change the value of by touch selecting **NEXT POINT**. Selecting **TERMINATE** brings you to this menu:

(1) DISPLAY TABLE OF
SPECIAL POINTS

(2) RETURN TO SEQUENTIAL
CHARACTERIZATION SECTION

(3) RETURN TO SPECIAL
POINT MENU

Touch select **(3)** to return to the menu in Step 2 above. Then select **(1)** again to return to the Special-Point Characterization Menu of Figure 4-8.

Touch select **CHARACTERIZE**. Then touch select **RETURN** to again return to the Special-Point Characterization Menu of Figure 4-8.

Touch select **ENTER OR CHANGE**.

5. The display prompts you with:

   NEW VOLTAGE (in Volts).....?_

   Use the keyboard to enter it and press the **RETURN** key.

   You are then prompted with:

   NEW FREQUENCY (in Hertz).....?_

   Use the keyboard to enter it and press the **RETURN** key.

6. Now you are prompted with:

   NEW CHAR. VOLTAGE (in Volts)..?_

   This option allows you to directly enter characterization constants developed by a separate procedure into 5200A-800 software. To continue with this procedure, simply enter the nominal value again.

7. Next you are prompted with:

   NEW UNCERTAINTY (in Percent)..?_

   This also is for characterization constants you have developed with a separate procedure. The only purpose of this uncertainty value is for display during automated 5200A-800 operation. If you are going to characterize the point with this procedure, enter an arbitrary uncertainty such as .001%.

Notes

UNCERTAINTY as entered above is used to display the uncertainty of a special point while 5200-800 software is in the Operate Mode. It is not used in the calculation of the characterized voltage. If you are relying on a characterized 540B for accuracy

enhancement, the AC/DC Difference correction factors must be taken into account, and the characterized voltage must be calculated and entered manually. This software does not automatically compensate characterized voltages even though a 540B AC/DC difference table was entered.

The characterized accuracy of the 540B, as provided in the test report accompanying a Fluke-characterized 540B, is valid only at the points listed in the table. Generally, the AC/DC Difference at 10 kHz is 25% of the difference at 20 kHz, and the difference below 10 kHz is assumed zero. These assumptions are valid, and the errors associated with them have been taken into account for the enhanced accuracy specifications. However, for special-point characterization, it is your responsibility to determine the correct AC/DC Difference for the point in question.

If special points are above 10 kHz and are not in the set of standard 540B characterized points, then a special 540B characterization should be performed at the point in question. Special 540B Characterization Points are available from the Fluke Standards Lab through any Fluke Technical Service Center.

8. This returns you to the Special-Point Characterization Menu (Figure 4-8). Now however your special-point value is displayed. Touch select **CHARACTERIZE** to call up the Special-Point Characterization Display shown in Figure 4-9.

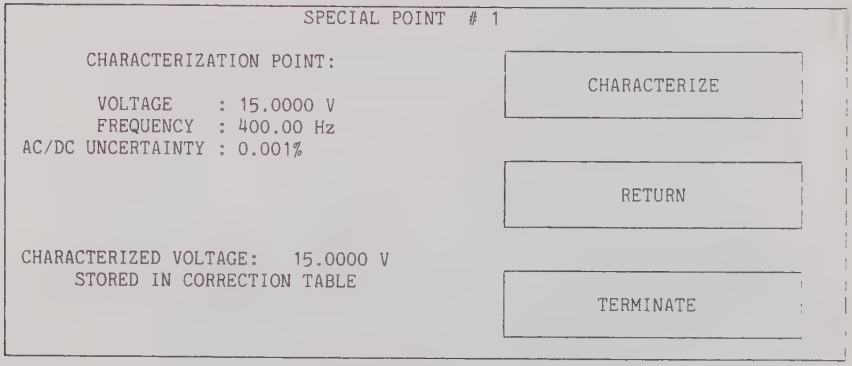


Figure 4-9. Special-Point Characterization Display

Touch select **CHARACTERIZE** again.

9. The controller responds with instructions for setting up the 540B, as in step 3 of **Sequential Characterization** above. The procedure is now

identical to steps 3 through 7 of **Sequential Characterization** except for one difference. Since you must set the 540B to a range that is equal to or greater than the value of the characterization-point voltage, the **PERCENT INPUT** indicator on the 540B may not be at 100%. This is normal in the case of a characterization point voltage that is not equal to a 540B range setting.

10. If you would like to enter an AC/DC difference constant for the 540B (or other thermal voltage converter) at this point, you may do so directly.

    For example, suppose you are characterizing at 5 V, 10 kHz, and the characterization process results in a 5200A setting of 5.00026 V. Referring to your TVC error data, you see (or calculate for this point) an AC/DC difference of -.0007% or -7 ppm (parts per million).

    A negative AC/DC difference error means that this TVC requires less AC than DC at this voltage/frequency point to produce the same thermocouple output. Accordingly, the 5200A setting of 5.00026 V was low by (.000007) X 5 V =

    Follow these steps:

    10a. Remove the "%" and change the sign.

    $$-(-.0007\%) \;/\; 100 = +.000007$$

    10b. Multiply by the nominal voltage setting to get an adjustment.

    $$.000007 \times 5\ V = .000035\ V$$

    10c. Add the adjustment to the corrected 5200A setting developed previously.

    $$\begin{array}{r} 5.00026\ V \\ +\ .000035\ V \\ \hline 5.000295\ V \end{array}$$

    10d. Round back to the appropriate 5200A resolution. In this example, the correct 5200A setting is 5.00030 V.

    10e. Enter the new corrected 5200A setting into the software table by selecting **ENTER OR CHANGE** from the Special-Point Characterization Menu of Figure 4-8. Enter the new corrected 5200A setting, as in step 5 above.

11. When you have characterized and entered all the special points, touch select **TERMINATE**. This records any new or changed values and displays this menu:

(1) DISPLAY TABLE OF
SPECIAL POINTS

(2) RETURN TO SEQUENTIAL
CHARACTERIZATION SECTION

(3) RETURN TO SPECIAL
POINT MENU

12. From this menu you can branch to other menus in the characterization program.

CHANGING SOFTWARE IEEE-488 BUS ADDRESSING

You can easily modify this calibration software to use different IEEE-488 Bus addressing for the 5440B or 5440A DC Calibrator and the 5200A AC Calibrator being characterized. Addressing is taken from variables set early in the **CALA** program.

For a 1722A, you need to modify the file **CALA_.BAL**. For a 1720A, you need to modify the file **CALA.BAL**. The address for the 5440B or 5440A is stored in variable **A1**. The address for the 5200A is stored in variable **A2**. These are part of a variable definition list located in line 2200 of each file. Be sure that you save the modifications onto disk and restart the software.

Following are step-by-step instructions to change the bus addressing. Where they are different, 1720A instructions are shown in [brackets].

1. Insert the 5200A-800 disk and press **RESTART**.

2. When the Start-Up screen appears, type **<CTRL>C**

3. Type **BASIC** [skip this step for 1720A].

4. Type **OLD "MF0:CALA_.BAL"** [**OLD "MF0:CALA.BAL"**]

5. Type **EDIT 2200**

6. Look for the variables **A1** and **A2**.

   Use the arrow keys to move the cursor to the numbers following = for A1 and A2. Press **DEL CHAR** and replace the number with the Bus Address that you would like to use. A1 is the 5440B or 5440A address. A2 is the 5200A address.

7. Type **<CTRL>C**

8. Remove the write-protect tab from the side of the disk cover and replace the disk in the disk drive. Then type **SAVEL "CALA_"**. [For 1720A, type **SAVEL "CALA"**]. Replace the write-protect tab on the disk.

System Builder's Guide

P/N 805424
JULY 1985
©1987 John Fluke Mfg. Co., Inc. All rights reserved.

FLUKE®

CONTENTS

1 INTRODUCTION AND SCOPE

Introduction 1-1
Definition of a System 1-1
Recognizing the Need For a System 1-2
System Development Overview 1-2

2 INTRODUCTION TO SYSTEM TYPES

Introduction 2-1
Test Systems 2-1
Measurement Systems 2-2
Control Systems 2-3

3 DEFINING THE FUNCTION OF YOUR SYSTEM

System Definition 3-1
    System Goals and Objectives 3-1
    System Needs Analysis 3-2
    Definition Review 3-3

4 PLANNING FOR SYSTEM DESIGN AND IMPLEMENTATION

Introduction 4-1
In-House System Development 4-1
System Component Vendors 4-1
Third-Party Organizations 4-2
Systems Responsibility 4-2
Costs and Staffing 4-3

5 DESIGN ISSUES

Introduction 5-1
System Specification 5-1
User Interfaces 5-4
Communications Techniques 5-5
Noise Sources and Solutions 5-6
    Noise Sources 5-6
    Noise Types 5-7
    Noise Solutions 5-9
    Floating Measurements and Guarding 5-10
    Noise Rejection Specifications 5-13
    Shielding Cables 5-15
Software Development and Operating Environment 5-16
Data Management 5-20
Applications Programming 5-22
Designing an Applications Software Package 5-23
Design Review 5-23

6 SELECTING SYSTEM COMPONENTS

Introduction 6-1
Support of Communication Techniques 6-1
Rack System 6-1
Environmental Considerations 6-1
Software 6-2
Systems Multimeters 6-3
Counters 6-5
Signal Generators 6-6
Calibrators and Standards 6-7
Switches and Switch Controllers 6-10
Programmable Power Supplies 6-12
Instrument Controllers 6-12
Terminals 6-13
Automatic Test Equipment (ATE) 6-14
- Component Testers 6-14
- Board-Level Testers 6-15
- Functional Testers 6-16
- Field Service Equipment 6-18

Thermometers 6-18
Data Loggers and Computer Front Ends 6-20

7 DETAILED DESIGN CONSIDERATIONS

Introduction 7-1
Difference Between a Sensor and a Transducer 7-1
Measurement 7-1
- Voltage 7-1
- Resistance 7-4
- Conductance 7-6
- Current 7-6
- Frequency 7-7
- Period 7-8
- Power 7-9
- Temperature 7-9
  - Thermocouple Temperature Measurement 7-10
  - Thermocouple Junctions, Probes, and Wires 7-13
  - Termocouple Measurement Error Sources 7-15
  - Resistance Temperature Measurement 7-15
  - RTD Measurement Error Sources 7-16
  - Semiconductor Temperature Measurement Techniques 7-17
- Strain 7-17

Signal Sourcing 7-22
- Voltage 7-22
- Current 7-25
- Resistance 7-25
- Frequency 7-25

User/Operator Interface 7-28
Video-Display Terminals (VDTs) 7-28
Light-Emitting Diode Displays (LEDs) 7-29
Liquid Crystal Displays (LCDs) 7-29
Vacuum Flourescent Displays 7-30
Analog Indicators 7-30
Data Management 7-31
IEEE-488 Bus Communications 7-31
Benefits of Using IEEE-488 7-32
Considerations When Using IEEE-488 in Systems 7-34
Basics of Using the IEEE-488 Bus 7-34
IEEE-488 Bus Control Computers 7-35
How the IEEE-488 Bus Operates 7-36
Bus Control Signals 7-39
Handshake Control Lines 7-39
Device Addresses 7-41
Messages 7-43
Interface Functions 7-46
Data Transfer Control (SH, AH, T, and L Functions) ... 7-46
Source Handshake 7-46
Acceptor Handshake 7-46
Talker and Extended Talker 7-47
Listener and Extended Listener 7-48
Service Request (SR Function) 7-50
Parallel Poll (PP Function) 7-50
Remote/Local (RL Function) 7-51
Device Clear (DC Function) 7-51
Device Trigger (DT Function) 7-51
Controller (C Function) 7-52
Electrical Interface Type (E Function) 7-52
RS-232-C Communications 7-53
Benefits of Using RS-232-C 7-53
Considerations When Using RS-232-C 7-53
How RS-232-C Works 7-54
RS-232-C Signal Definitions 7-57
RS-449, RS-422, RS-423, and RS-485 Communications 7-59
How RS-422 Works 7-60
How RS-485 Works 7-63
Computer Data Networks 7-65
ISO Reference Model 7-65
Network Topologies 7-76
Network Channel Control 7-69
Network Physical Implementation 7-70
Telephone and Other Carrier Systems 7-70
Current Loops 7-71
How a Current Loop Works 7-71

Modems and Multiplexers 7-72
Modems 7-72
How Modems Work 7-72
Baud vs Bits Per Second 7-73
Full- and Half-Duplex Communication 7-73
Synchronous vs Asynchronous Communication 7-74
Modem Standards 7-74
Multiplexers 7-76
How Multiplexers Work 7-76
Software 7-76
Detailed Software Design 7-77
Program Design Language (PDL) 7-79
Rack and Enclosure Systems 7-84
19-Inch Rack Dimensional Standards 7-85
Rack Environmental Standards 7-86
NEC Classes 7-86
NEC Groups 7-86
NEC Divisions 7-86
NEMA Terminology for Enclosures 7-87
Rack Cooling 7-88

8 IMPLEMENTING YOUR SYSTEM

Introduction 8-1
Purchasing System Components 8-1
Building Custom Components 8-2
Writing Applications Software 8-3
Systems Integration 8-4

9 TESTING YOUR SYSTEM

Introduction 9-1
Informal Testing 9-1
Element Tests 9-1
Functional Tests 9-2
Acceptance Tests 9-3

10 INSTALLING YOUR SYSTEM 10-1

11 MAINTAINING YOUR SYSTEM 11-1

SECTION 1

INTRODUCTION AND SCOPE

CONTENTS

Introduction 1-1
Definition of a System 1-1
Recognizing the Need For a System 1-2
System Development Overview 1-2

We recognize that the customer is our boss; we exist to serve his needs, and he has the right to get a little more than he thinks he has paid for.

John M. Fluke

INTRODUCTION

These are the words of John M. Fluke, founder of the John Fluke Manufacturing Company, and we try to live by them. This philosophy is especially important in the application of our electronic test and measurement equipment to systems. Systems are either more or less than the sum of their parts, depending on how well they are designed, built, installed, operated, and maintained.

Although many of the general principles presented in this book can be applied to other types of systems, this book is intended for builders of electronic test, measurement, and control systems.

This book exposes you to the issues you will have to address during the life of your system. The life cycle of a system begins when you first start planning the system and continues until the system is deactivated. You will not find every question answered here, but if this book helps you to ask the proper questions, it will have done its job.

DEFINITION OF A SYSTEM

Webster defines a system as "a regularly interacting or interdependent group of items forming a unified whole." This is an appropriate definition for an electronic test, measurement, or control system. These kinds of systems are usually composed of more than one system component (a group of items), that communicate with each other, interact, and depend on each other for accomplishing a set of interdependent tasks. The skill of the system builder determines whether or not the system presents a "unified whole."

Electronic test, measurement, and control systems are built the way they are because of economics. Designing and building a complete system for each application is very expensive. Because of this, modern electronic systems are built by combining system components. Each system component is designed to do one or more major functions within a system. For example, a computer system may combine such system components as a Central Processing Unit (CPU), Memory Units, and Interface Devices into a system that does general computing tasks. A different computer system may replace only the Interface Devices and retain the rest to do process monitoring and control tasks. This interchangeability of system components is a foundation of modern electronics design.

RECOGNIZING THE NEED FOR A SYSTEM

The following are some questions to ask yourself before starting the design of a system:

1. Is the task varied? Humans, because of our adaptability, handle tasks with high variability better than even the best computer systems. The application of artificial intelligence to computer systems may change this in the near future.

2. Does the task have a low repetition rate? It may make more economic sense to have humans do low rate tasks. However, if the task has a high repetition rate, an electronic system may be justified.

3. Does a data base have to be maintained or a complex report generated based on the results of the task? An advantage of electronic systems is their ability to capture data and generate reports in addition to their main functions.

4. Does someone already make a device or system that is similar to what you want? If so, you should investigate adapting that system or device for your use. It wastes resources to design a system that could be created with off-the-shelf parts.

SYSTEM DEVELOPMENT OVERVIEW

The following are some rules for system development. These concepts are expanded in the following sections of this book.

1. Define and specify before you design, design before you build, build what you designed, then test before you release the system for use.

2. Do a formal review of the system development project at least after the Definition, Design, and Testing phases. Support these reviews with formal documentation describing the work done during each phase.

3. Expect to spend just as much money and resources on maintenance over the life of the system as you did designing and implementing the system.

4. Retest the system every time a change is made to make sure that the system specifications are maintained.

SECTION 2

SYSTEM TYPES

CONTENTS

Introduction 2-1
Test Systems 2-1
Measurement Systems 2-2
Control Systems 2-3

INTRODUCTION

This book addresses three basic types of electronic systems:

Test Systems
Measurement Systems
Control Systems

These three types of systems have much in common. They all measure the value of physical parameters. Moreover, they provide stimuli as either physical parameters or data.

TEST SYSTEMS

The primary function of a test system (Figure 2-1) is to determine if another device or system is operating according to its specifications. The device being tested is referred to as a Unit Under Test (UUT). The test system may be as simple as a gauge for determining if a dimension is correct (this is not so simple when high precision is involved), or as complex as a ground test system for a jet fighter.

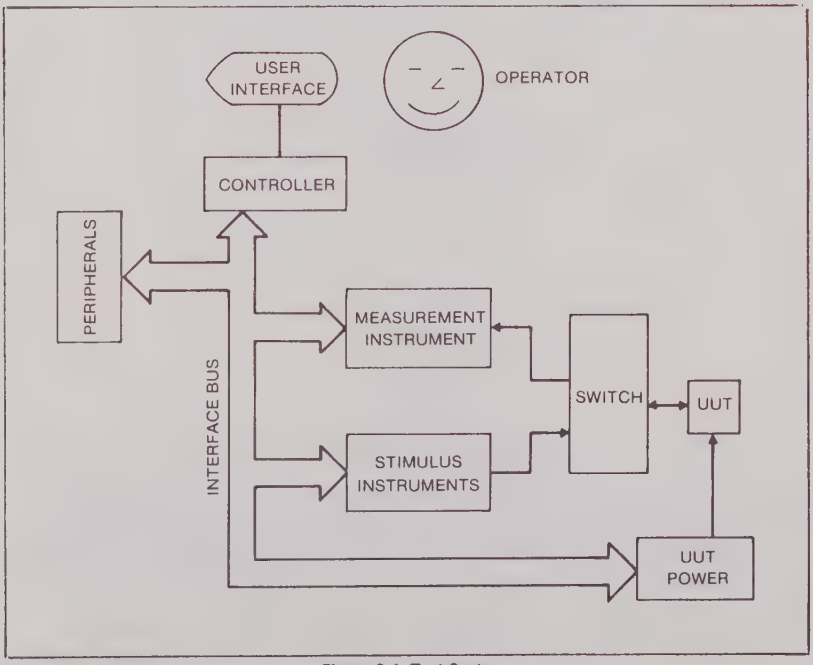


Figure 2-1. Test System

A test system is designed around the the needs of the UUT. Testing a typical electronic UUT will require that the system provide power, force stimuli, and measure responses. The system may also be required to provide automatic control functions to the UUT or make provisions for an operator to provide these control functions. The system must also be designed around the size, weight, shape, and connector pinout of the UUT.

MEASUREMENT SYSTEMS

Measurement systems (Figure 2-2) are conceptually simpler than either test or control systems. The main function of a measurement system is to provide information about a process to an operator or another system. This information may be used to drive alarms or to generate reports. Most measurement systems are really control systems, where the control is done by the operator or another system. This control is based on information acquired by the measurement system.

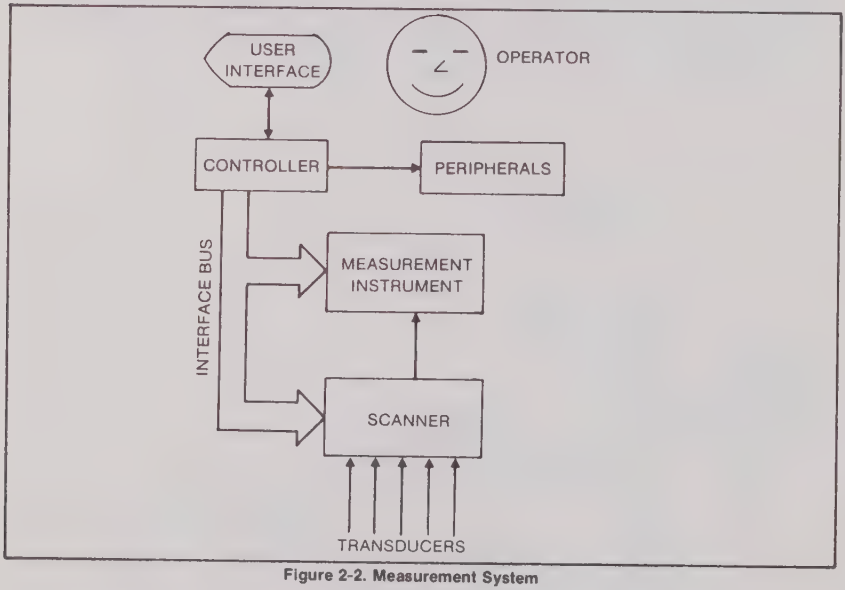


Figure 2-2. Measurement System

A measurement system provides for the conversion of physical parameters into a form suitable for presentation to the operator or another system. Because of this, measurement systems are designed around the needs of the end user of the information. Measurement systems may also be called on to do computations on the acquired data. This operation is termed Data Reduction and is done to make the ultimate information more useful. The system may be as simple as a few digital thermometers being read by an operator or as complex as a process monitoring panel for an oil refinery.

CONTROL SYSTEMS

The main function of a control system (Figure 2-3) is to keep one or more process variables within acceptable bounds. Process variables are any parameters that can be influenced by the control system. The control system periodically measures the value of the process variable (or some parameter that is related to the process variable), does computations by following a control algorithm, and applies stimulus to the process to maintain the process variable within the allowed limits.

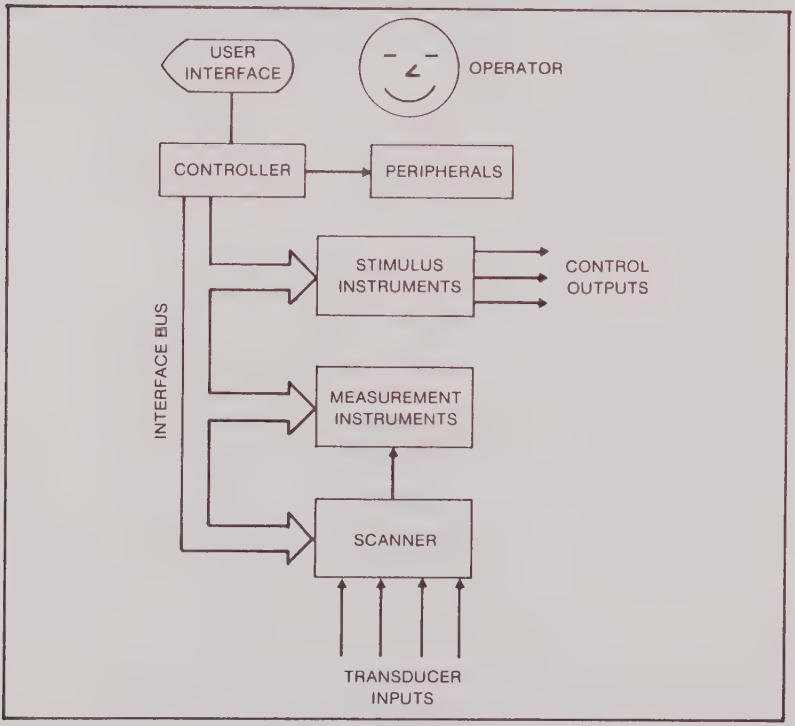


Figure 2-3. Control System

Control Systems are designed around the needs of the process under control. A control system may be as simple as the thermostat that controls your home furnace or as complex as the distributed control systems that are found in chemical plants or nuclear reactors.

SECTION 3

DEFINING THE FUNCTION OF YOUR SYSTEM

CONTENTS

System Definition 3-1
System Goals and Objectives 3-1
System Needs Analysis 3-2
Definition Review 3-3

SYSTEM DEFINITION

Definition is the first step in building a system. A system that is not defined can't be designed.

A system definition should be a written document. This document forms the foundation for the work that follows, so it should be complete and clearly written.

Above all, the system definition document is a communication device. It should communicate the philosophy and goals for the system to everyone involved in the system building effort. Often, a missing or poorly written system definition is the cause of major system design and implementation problems.

System Goals and Objectives

To define your system, first write a statement of goals and objectives. State what you expect the system to do in clear, concise language. For example:

> The new control system for the #1 boiler system will decrease the cost of operating the unit by optimizing the fuel and air mixture in the burner box over varying weather conditions.
>
> -or-
>
> The Automatic Subassembly Test System for the serial interface card will increase the unit test rate to 100 assemblies per hour while decreasing the false rejection rate to 1 per 100,000 assemblies. It will allow a false pass rate of less than 1 per 1,000,000 assemblies. It will also provide information on parts failures, in the standard format, to the central components data base.

If the goals and objectives of a system are complex, list them in order of priority. Doing so allows the designer to make trade-offs if some of the goals and objectives cannot be met.

Distribute copies of the statement of goals to everyone concerned with the system. Make sure that everyone is in agreement on the goals and objectives before continuing with the definition process. Be responsive to changes and additions to the goals and objectives statement. Changes will become more and more difficult and expensive as the system development process proceeds, so make any necessary changes as early as possible.

System Needs Analysis

The next step is to analyze the needs of the UUT, process, or data user. The orientation of the system will be different depending on its type. As described in Section 2, test systems are oriented toward the needs of the UUT, control systems are concerned with the needs of the process, and measurement systems must be defined with the ultimate user of the data in mind.

The following are some common analysis steps that must be done during the system definition process:

1. Analyze the need for measurements. What type of physical parameters must be measured? How many measurement points of each type must there be? To what accuracy and resolution must the parameter be measured?

2. Analyze the need for stimulus. What form must the stimulus take? How many stimulus points of each form must there be? How much power must be supplied?

3. Analyze the need for data reduction and conversion. Derive and write down any algorithms that must be used.

4. Analyze any timing constraints. How often must control stimulus be updated? How fast must tests be done? How soon after an event is detected must alarms be triggered?

5. Analyze existing and required data communication facilities. Is there an installed facility that must be used? Is there enough capacity for the new system? What new facilities must be purchased or built?

6. Analyze the need for operator interaction. What type of operator interface should be used: graphics, process diagrams, statistics, numbers, ticket printer? what type of input devices should be used: keyboard, touch-sensitive screen, custom controls?

7. Analyze the operator skill level and the human factors involved in the system. The operator must be capable of operating the system. However, the operator must not be presented with so much information that it becomes impossible to interpret. Moreover, the operator must be presented with enough information to keep track of what is going on, especially during error or fault conditions. The operator should be able to reach all the controls and read all the indicators.

8. Analyze the need for reports. Who will require information from the system? For what will they use the information? Don't assume that everyone needs every piece of data.

9. Analyze the need for sharing data with other systems. Sometimes large increases in efficiency can be gained by sharing data between systems or having a large system gather information from many smaller systems for reduction and analysis.

10. Analyze any significant environmental constraints on the system. Determine if the system has to operate in a hostile environment. What's the power situation? What type of enclosures need to be built? What's the best location for the system? Test systems can usually be placed on the manufacturing floor, but measurement or control systems may have to be located some distance from the process to be controlled or monitored.

When you have completed and written down the analysis, you have a complete definition of what the system is to do. You do not, however, have a design. A definition states what the system is to do; the design specifies how this is to be accomplished. The rest of this book leads you through the process of going from definition and through the design, implementation, and installation stages to a working, maintainable, productive system.

Definition Review

When the definition is complete, have it reviewed by the same people who reviewed the goals statement. Be responsive to changes in the definition. Changes at this stage are inexpensive compared to changes later in the design cycle. Do not, however, allow the definition to get too loaded with unnecessary features.

Once everyone agrees to the definition, you need to start doing the detailed system specification and design. However, before you start this task, determine who is going to design, implement, and test the system. You also need to budget for the expenses involved in the system development process and construct a schedule to follow during the development cycle. The next section discusses these issues.

SECTION 4

PLANNING FOR SYSTEM DESIGN AND IMPLEMENTATION

CONTENTS

Introduction 4-1
In-House System Development 4-1
System Component Vendors 4-1
Third-Party Organizations 4-2
Systems Responsibility 4-2
Costs and Staffing 4-3

INTRODUCTION

Planning for system design and implementation should proceed in parallel with system definition. The first issue to address is, "Who will do the work?" Three organizations may be involved in system design and implementation. These organizations are in-house system development groups or individuals, system components vendors, and third party systems firms. These groups are described and contrasted in the following sections.

IN-HOUSE SYSTEM DEVELOPMENT

The person best equipped to handle the task of developing a system is the person who knows the most about the application. The most difficult task in system development is the transfer of definition information between the applications expert and someone else involved in the system development. Remember, it has taken an applications expert years of experience to acquire knowledge about the application. This sort of knowledge is difficult to transfer to someone else.

Unfortunately, the applications expert may not have all of the skills required to do the entire system development job. Also, on large systems, the magnitude of the tasks may require a team effort. Because of this, it is often necessary to employ people other than the applications expert in the systems development process.

System development requires the involvement of Hardware Design Engineers, Software Design Engineers, Instrumentation Engineers, Facilities Designers, and Project Managers. Often, it is much more cost-effective to maintain a central group of people with these skills. This in-house system development group contracts with the department needing a system to do the system development tasks.

The primary difficulty in using in-house development groups is in the definition of the system. Many times, because the development group is within the company, the system definition is not as complete as it could be. Remember that the in-house development group may not have the applications expertise that the local expert has. The tasks of system definition and specification cannot be ignored just because an in-house team is doing the work.

SYSTEM COMPONENT VENDORS

The system component vendor is an important member of the development team. Many times, vendors offer services that can be critical to the success of the system development effort. These services include consulting, training, maintenance services, hot-line telephone advice, packaged software, modifiable software, custom enclosures, custom component design, etc.

You should arrange a meeting with representatives of each of the potential vendors of the system components to find out about the additional services that they offer. Often, it will be more cost-effective to purchase slightly higher priced components for your system from a company that offers the best services package.

THIRD-PARTY ORGANIZATIONS

Third-party organizations are firms involved in the system development, other than the system component vendor(s) and the firm that will be installing and using the equipment. Third parties include Consultants, Construction and Engineering firms, OEMs, Systems Houses, and Software Houses. These organizations are described below.

- A Consultant is an individual or company that provides consulting services to customers on hardware and software selection and application. A consultant usually has expertise in the customer's specific area of application. A consultant usually does not purchase equipment directly, but influences the ultimate purchase. Some consultants also act as a software house (see description below).

- A Construction and Engineering Firm (C&E firm) is a company that provides engineering and installation services to end users -- normally in physical plant construction. These firms may retain the services of Consultants, Systems Houses, and Software Houses during a construction or design project.

- The End User is the one who ultimately uses the system to achieve a solution to their measurement, control, or testing problems.

- An Original Equipment Manufacturer (OEM) is a company that uses a vendor's manufactured products or services to enhance the value or their own end product. OEMs inventory vendor products and commit to a specific volume of future purchases of a vendor's products.

- A Systems House is a company that converts hardware and software into solutions for end user applications. Systems Houses usually buy components from several hardware and software vendors and design a total system according to the customer's requirements. Their tasks include racking and stacking, interconnecting the various components, writing custom software, installing, testing and documenting the entire system. System Houses often take total systems responsibility.

- A Software House is a company that designs, writes, tests, and installs computer software according to a customer's requirements. Software houses differ from systems houses in that they rarely do hardware design or configuration. Also, software companies are rarely application experts.

SYSTEMS RESPONSIBILITY

Responsibility for the various parts of the system, including definition, design, component purchase and implementation, integration, installation, training, support, and maintenance must be assumed by one or more of the parties involved in the system development. All parties involved should understand who will assume these responsibilities.

One firm involved in the system development must assume responsibility as the prime contractor or supplier. The prime contractor or supplier

coordinates the activities of all the other parties involved in the system development.

In-House System Development Groups, System Houses, and C&E firms usually assume full responsibility for the design, purchase, implementation, integration, installation, training, support, and maintenance of the system. Consultants, on the other hand, usually assume responsibility for only the design and sometimes the implementation and integration of a system. System Component Vendors sometimes take prime responsibility for a system, but, for the most part, prefer that either the system user or a third party take on this responsibility. Software Houses rarely take prime responsibility for the system.

COSTS AND STAFFING

Custom system development is an expensive endeavor, not only in terms of money, but also in personnel and material resource use. When a company produces a standard system, they can sell the same thing many times, spreading the development costs over all the systems sold. Custom systems, on the other hand, are produced in limited quantities, so the development costs must be assigned to the few systems produced. As a result, it is always less expensive to purchase a standard commercial system than to develop a custom system. Unfortunately, a standard commercial system that performs the required functions may not exist. In this case, a custom system must be developed.

Enough resources must be allocated to the system development. A development effort that is understaffed or has too limited a budget will have problems that may affect the ultimate success of the system.

The staff for a system development project usually includes one or more hardware and software designers, an applications expert, a facilities manager, a communications expert, and a manager. One person can handle the design of more than one aspect of a small system. Also, some of the staff can be shared with other development projects or tasks. For example, the facilities manager may need to participate only during the definition, specification, and installation stages of the design. Consultants and other third parties may be hired to do selected portions of the development. System houses may be contracted to do the entire development.

System development costs are not limited to the cost of the components and development staff. Special facilities may need to be purchased or leased during the development process. One of the more expensive facilities of this type is a software development facility. This issue is discussed in Section 5.

Software design, implementation, and testing are among the most difficult aspects of system development to properly budget and plan. Software development productivity varies from under 10 lines of code per person-day to as much as 60 lines. The variance is caused by many factors. The ease of transition between the design technique used and the implementation language is an important factor. Productivity can be greatly increased by:

- Using structured design techniques and a program design language (described in Section 7).
- Writing the code in structured implementation language (like Pascal, C, or Ratfor)

Packages of existing software can sometimes be used or modified to do some of the system functions. It pays to maintain a library of commonly used functions so that they can be reused on future projects.

In general, the productivity of any member of the system software design team is a function of:

1. The complexity of the design.
2. The availability of existing algorithms or function libraries.
3. The design techniques used.
4. The implementation language used.
5. The level of testing required.
6. The amount and formality of the documentation required.
7. The quality of the software development facility.
8. The amount of time required to support tasks and functions other than the system development. This includes maintenance of older systems, corporate functions, consulting with other groups, education, management, etc.
9. The experience and skill level of the individual.

With this many variables, accurate resource allocation and scheduling of software projects is difficult. The system development manager must analyze all of these factors before developing a schedule.

SECTION 5

DESIGN ISSUES

CONTENTS

Introduction 5-1
System Specification 5-1
User Interfaces 5-4
Communications Techniques 5-5
Noise Sources and Solutions 5-6
    Noise Sources 5-6
    Noise Types 5-7
    Noise Solutions 5-9
    Floating Measurements and Guarding 5-10
    Noise Rejection Specifications 5-13
    Shielding Cables 5-15
Software Development and Operating Environment 5-16
Data Management 5-20
Applications Programming 5-22
Designing an Applications Software Package 5-23
Design Review 5-23

INTRODUCTION

This section introduces the issues you must consider when designing a system. Using the general information here and the more detailed information in later sections, you should be able to design the system.

Before designing the system, be sure that the system definition is complete, reviewed, and approved by the appropriate people. The further the development process proceeds, the harder it will be to change the design of the system. A good rule to follow is "make changes early."

While the work is proceeding on the system specification, you should be working with vendors of system components and selected third parties (see Section 4 for definitions). Ask each vendor to submit a recommendation on the system configuration. Be sure to use these only as recommendations. Don't let the the system vendor design the system for you. The vendor does not know the application as well as you and may not understand the fine details of what the system is to do.

SYSTEM SPECIFICATION

The first thing to do when designing a system is to expand the system definition into a system specification. The system specification includes much more detail than the definition, and is intended for technical readers. The system specification includes the following information over and above that in the system definition:

1. An implementation strategy. This should include an identification of the type of components (not specific models or manufacturers) to be used to implement functions outlined in the definition. It also should identify who will do the work (in-house group, third party, component vendor, various combinations, etc). It must include a schedule and budget.

2. A detailed block diagram (Figure 5-1), showing how the system is to be separated into modules. Take the implementation strategy into account when doing this. If the strategy is to use commercially available instruments and computers to implement the system, then each module in the block diagram should match a kind of generally available product.

3. A detailed listing of all input and output points in the system, including cabling requirements, type of media to be used (copper wire, thermocouple wire, fiber-optic cable, etc), and distance requirements.

4. A detailed list of all functions the system must do. This list should show the implementation strategy for each function. It should show whether the function is to be implemented in hardware, software, or a combination of hardware and software.

5. A floor plan showing the installation location for the system. This should include all electrical power connections, air conditioning duct placements, power isolation facilities, air, gas, or vacuum requirements, etc.

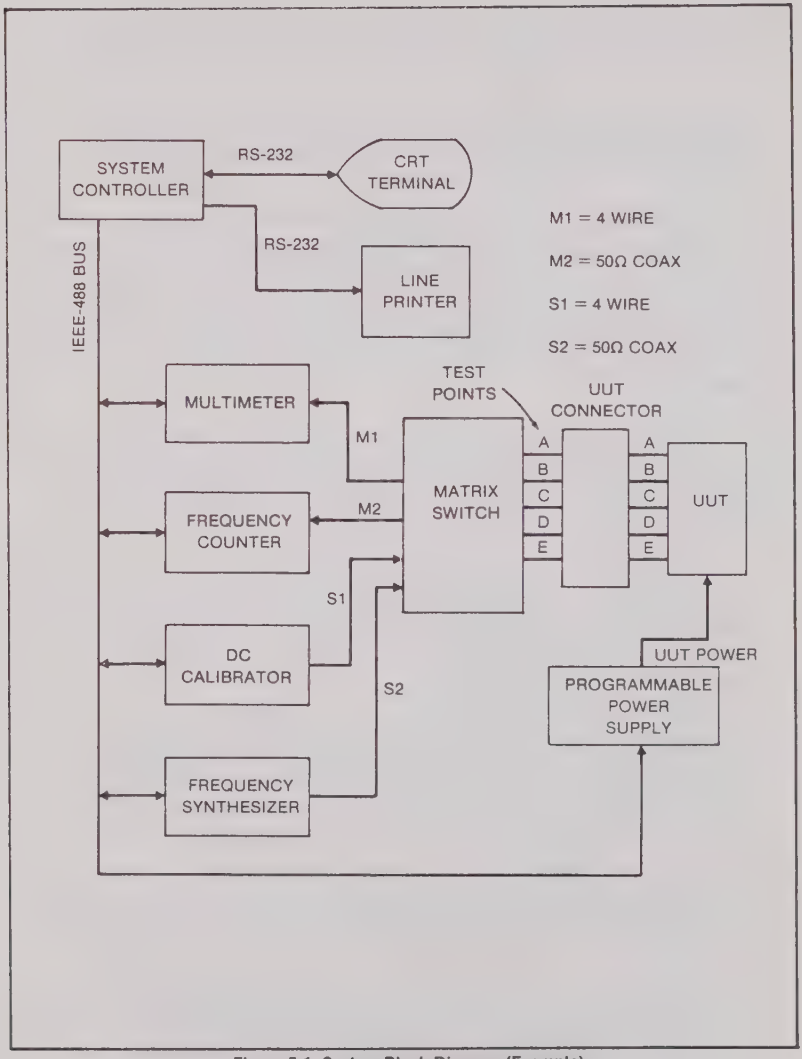


Figure 5-1. System Block Diagram (Example)

This example shows how a cable requirements list would appear:

DATA CABLE REQUIREMENTS

Remote Instrument	Length	Type
CRT Cable	10 ft.	RS-232-C
Printer Cable	30 ft.	RS-232-C
Multimeter	1 m	IEEE-488
Counter	1 m	IEEE-488
Calibrator	2 m	IEEE-488
Synthesizer	4 m	IEEE-488
Power Supply	4 m	IEEE-488
TOTAL	12 m	IEEE-488

SIGNAL CABLE REQUIREMENTS

Multimeter	20 ft.	4-wire #20, stranded & shielded
Calibrator	20 ft.	4-wire, #16, stranded & shielded
Counter	25 ft.	RG-58 50 ohm coax with BNC plugs
Synthesizer	30 ft.	RG-58 50 ohm coax, BNC plug at one end and jack at the other
Power Supply	10 ft.	4-wire #10 stranded

Here is an example of a system function list:

Function 1: Apply 110 Volts at UUT power, measure UUT DC power at Test Point A (5 volts nominal).

Function 2: Measure clock frequency (10 KHz nominal) at Test Pont B.

Function 3: Apply 13.5 VDC at Test Point C and a 37.5 MHz, .5 Vrms signal at 35% amplitude modulation at 35 KHz to Test Point C. Measure AC rms voltage at Test Point D (.35 Vrms nominal) and the frequency at Test Point E (35 Khz nominal).

Function 4: Keep the same connections as in Function 3, but sweep the modulation frequency from 1 KHz to 50 KHz in 1 KHz steps. Measure the frequency at Test Point E and the voltage at Test Point D at every different modulation frequency.

USER INTERFACES

User or operator interfaces are the way that humans interact with the system. Interfaces may consist of a few lights and buttons or a large room full of indicators, video display terminals, and control panels. The design of the user interface determines how well the system functions are accepted.

A system usually has more than one type of user interface. The designer and maintainer of a system may need one type of interface while the operator may need another. A good rule to follow is:

> Don't present a user with more functions or information than are needed.

If a single interface is to be used by more than one type of user, make the interface reconfigurable; or design in a lockout for some functions. A lockout can be a lockable door over some of the controls or a software routine that permits only certain keys to be pressed by some users.

Section 6 details some of the specific equipment that can be used to implement user interfaces.

COMMUNICATION TECHNIQUES

Communication binds a system together. Communication within an electronic system involves two kinds of data: digital and analog. The current trend is toward more digital communication and less analog.

Analog communication consists of signals passing between devices in the system or into or out of the system. In this type of communication, the information carried by the signal is a function of one or more parameters of the signal. For example, the voltage output by a thermocouple carries information about the temperature of the thermocouple junction. The amplitude of a sine wave may represent the current condition of an amplifier.

Environmental conditions can alter the information content of an analog signal, because the parametric value of analog signals carries the information. For example, subjecting a thermocouple to a large magnetic field may affect the apparent measured temperature. Electrostatic noise from a high voltage power supply may disturb the apparent amplitude of a sine wave. Because of these types of problems, most modern electronic systems convert analog information into digital form as close as possible to the source of the signal.

Digital communications consist of signals that can be in only a few different states. In much digital communication there are only two signal states: ON and OFF. Any other state is interpreted as illegal.

In digital communication, information is carried as a group of states of the signal or as a group of transitions of the signal from one state to another. For example, a 4- to 20-mA current loop communication consists of a series of **mark** states and **space** states of a current signal. A mark state consists of a current of 20 ma or more flowing in the signal wire. A space is indicated by less than 4 ma of current flow.

Because digital signals have few legal states, they are less prone to alteration by environmental effects. A large magnetic field may inhibit communication in a 20-mA current loop system, but it would rarely alter the information. Digital signals often include error detection information along with the normal data to allow bad transmissions to be detected and corrected. Digital communication over long distances and in noisy environments is possible because of these techniques.

Section 6 gives details of several digital communications techniques.

NOISE SOURCES AND SOLUTIONS

The most common source of error in measurement and control systems is electrical noise. Good design is the best defense against a possible noise problem. Potential noise sources should be identified and eliminated or minimized during the design of the system. Proper connections between signal sources and measurement devices can minimize noise pickup at little cost. The selection of system components (especially measurement devices) with good noise rejection specifications is a key factor in a successful system design.

To design a system with good noise performance, the designer needs a basic understanding of noise sources and reduction techniques. The discussion of these topics follows.

Noise Sources

There are five common sources of noise in electronic systems:

1. Electric Field (or electrostatic)

   Electrostatic noise is a voltage induced on a conductor because of its proximity to a source of varying charge.

2. Inductive Pickup

   Inductive pickup is a current induced in a conductor because of its proximity to another conductor carrying a variable current.

3. Radio Frequency Interference (RFI)

   RFI is a current induced in a conductor because of the presence of a high frequency electromagnetic field.

4. Power line noise

   Power line noise enters the system over the commercial power lines, or is generated by equipment in the system.

5. Ground current loops

   Ground current loop noise is a current that comes about because of poor quality ground connections or differing common-mode voltages within the system.

These sources of noise have all been lumped under the title "Electromagnetic Interference" or "EMI." Any of these noise sources can be located either inside or outside the system.

Noise Types

There are two types of noise in electronic systems (see Figures 5-2 through 5-5):

1. Common-mode noise. Refer to Figure 5-2. These noise signals are common to all signal lines. For example, if both of the wires from a thermocouple have a 220-volt 50-Hz signal on them with respect to earth ground, this is considered to be common-mode noise.

2. Normal-mode noise. Refer to Figure 5-3. This type of noise is superimposed over the the actual signal. For example, if there is a 10-mV, 60-Hz signal between the two wires from a thermocouple, this is considered to be normal-mode noise. Normal-mode noise is much more difficult to deal with than common mode noise.

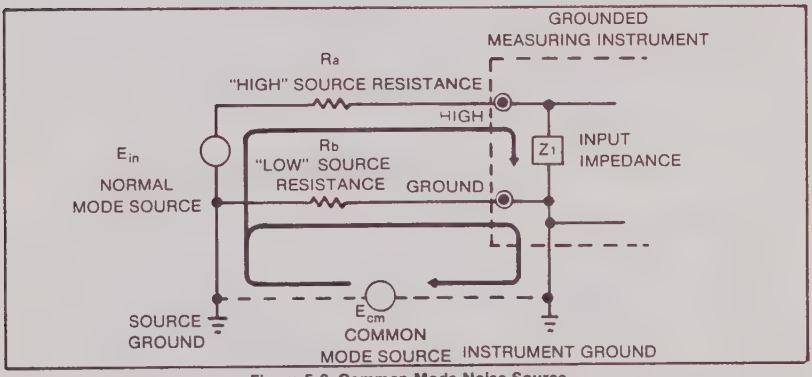


Figure 5-2. Common Mode Noise Source

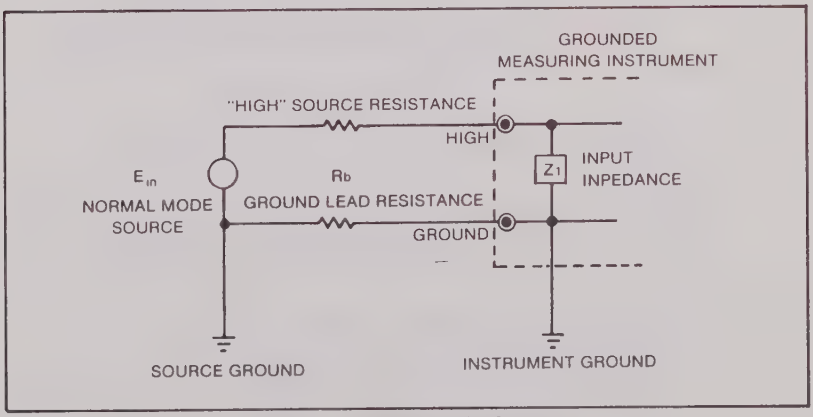


Figure 5-3. Normal Mode Noise Source

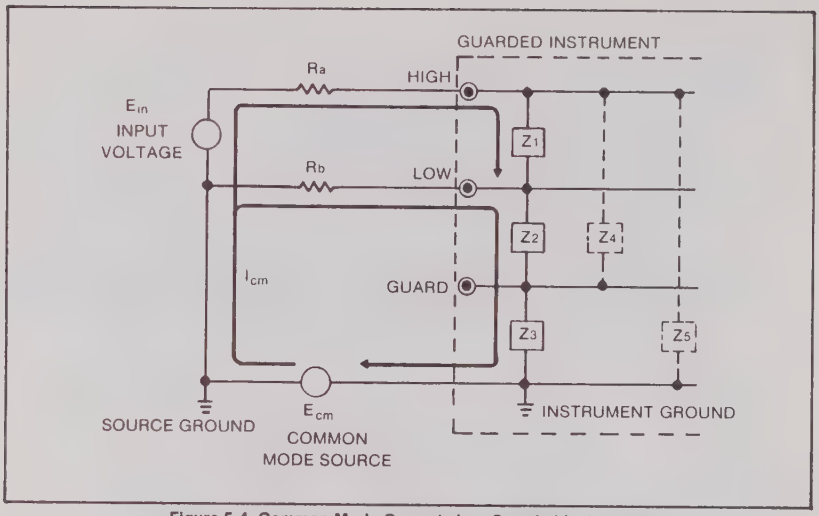


Figure 5-4. Common Mode Currents in a Guarded Instrument

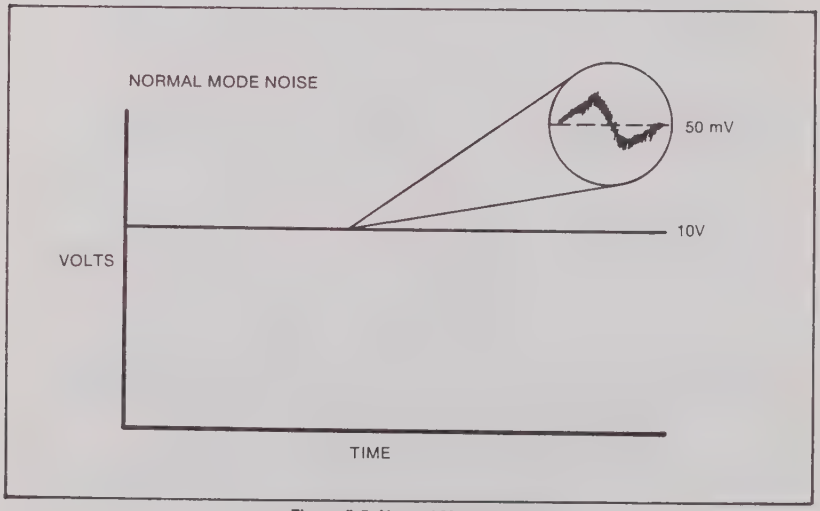


Figure 5-5. Normal Mode Noise

Noise Solutions: Electrostatic Noise

Electrostatic noise sources include high voltage power supplies in video display terminals and TV sets, switching power supplies, power transmission lines, and other sources of high voltage charge.

Shielding and guarding are used to minimize electrostatic noise. Use a metal shield between the noise source and the signal. The metal must be a good conductor of electricity and must be well grounded. Braided shielding is often used in cables. Foil wrappings are better than braided shielding, especially for high frequency noise. Guarding techniques are discussed later in this section.

Noise Solutions: Inductive Pickup Noise

Inductive pickup is caused by a conductor's proximity to another conductor that is carrying an alternating current. Inductive pickup is common in cables and conduits that carry many different wires. Other sources include transformers, motors, ac power lines, etc. Inductive pickup can be minimized by using twisted pair signal wires. Steel cases or cabinets are used to shield against inductive pickup, but these are heavy and expensive.

Noise Solutions: Radio Frequency Noise

Radio frequency noise sources include digital circuits, motor brushes, solenoids, coils (like TV and VDT deflector coils and flyback transformers), the local radio or TV station, and anything else that generates a high frequency electromagnetic field. A major problem caused by a heavy RFI environment is noise pickup in the recording heads and circuitry of magnetic recording equipment. RFI can cause read and write errors in this type of equipment.

The primary method of reducing electromagnetic noise is to purchase system components designed for maximum RFI rejection. Other techniques include using small shunt capacitors across signal lines, using shields, and using guarded measurement techniques (described below).

Noise Solutions: Power Line Noise

Power line noise gets into a system over the electric power lines. The best defense against this type of noise is to eliminate it before it gets to the system. There are many types of power line filters available. Some instruments have such filters built into their power supplies. Make sure the line power surge protection specifications for each of the system components are adequate. This type of power line filtering protects against surge and high frequency noise, but does little about fade or dropout.

While power line surge and noise may case measurement errors in the system, power line fade and dropout may cause the system to fail altogether. Even in countries where the commercial power system is good, fade and dropout are the most common power line problems.

Power line fading is caused by anything from a sudden demand change on the commercial lines, to a motor starting up in some part of your own facility. Dropout is caused by line switching and surge protection equipment and large load variations.

The only method of solving fade and dropout problems is to use an Uninterruptible Power Supply (UPS) to supply line power for the system. A UPS is a large battery that powers a dc to ac converter. The battery is charged off the commercial lines.

In a switching UPS, the system is powered by the commercial lines until a fade or dropout is detected. When an event is detected, the UPS switches the power for the system onto the battery-powered dc to ac converter. In other UPS devices, the system is always powered from the dc to ac converter, and the battery is constantly charged by the commercial power lines. When using a switching UPS, the components of the system must be able to survive the power dropout between the time that the power line event happens and the time that the UPS can get the line switched to the battery-operated supply.

Noise Solutions: Ground Loop Currents

Ground loop currents are caused by poor grounds in the system or by the grounds in a system at different potentials with respect to each other. See Figure 5-3.

To minimize ground noise, use floating measurement techniques (described next) and make sure all equipment in the system is grounded to the same point. Ground loops are often created by a sensor attached to a point with voltage on it. Here, a current may flow down the signal lines, through the measurement instrument, along a communications line, and finally to a ground at another device. The voltage developed by the current flowing in the signal lines is read as part of the measurement. This type of noise can be avoided by using a floating measurement device or an insulated sensor.

It is sometimes necessary to use an isolation transformer to isolate the line power from the general power system into the system. These transformers contain shielding to prevent high-frequency noise from entering the power lines inside the system. They also break the ground connection, establishing a ground that is isolated from the power system ground. Use of an isolation transformer, while expensive, can solve many power-related noise problems in a test, measurement, or control system.

Floating Measurements and Guarding

Many noise problems can be solved or minimized by using floating measurements with a guard. A floating front-end measurement device has a very high impedance between the measurement terminals and the instrument ground. A guarded instrument has an additional shield between the low terminal and ground (see Figure 5-6). A connection to this guard shield is usually available at a terminal so the system designer can connect the guard shield to an appropriate place in the external circuit.

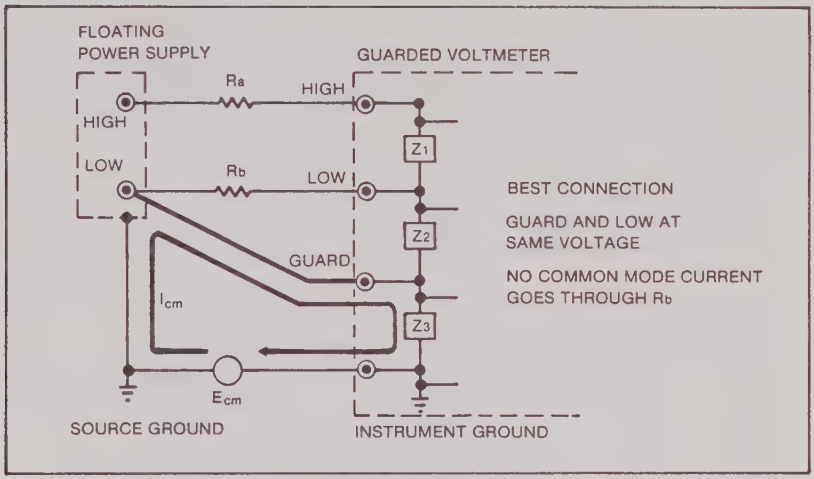


Figure 5-6. Best Guard Connection: Guard to Low at Source

Floating measurement and sourcing techniques minimize the currents that would normally flow in lead wires because of the common-mode voltages between measurement and stimulus points and the instrument ground. Current flow, due to common mode voltages, can cause measurement errors because of lead and switch resistances (see Figure 5-3).

Use of a guard connection in addition to floating measurement techniques can further decrease common mode currents by shunting these currents away from the measurement leads. However, the guard must be properly connected, as described in these guidelines:

1. Connect the guard so that the guard terminal and the low terminal on the instrument are as close to the same voltage as possible.

2. Connect the guard so that most or all of the common mode current flows through the guard connection rather than through the measurement leads.

3. If possible, connect the guard to the low measurement lead at the point of the measurement, as shown in Figure 5-6. If this is not possible, connect the guard to the low measurement lead at the instrument (Figure 5-7).

4. **CAUTION: DO NOT CONNECT THE GUARD TO GROUND AT THE INSTRUMENT!** This not only defeats the purpose of the guard but, it may also damage the instrument (see Figure 5-8). Most instruments have a lower breakdown voltage rating between low and guard than they have between low and ground. Connecting guard to ground has the effect of reducing the voltage breakdown rating of the instrument.

5. Don't leave the guard open. Any connection, such as guard to low, is better than an open guard. Most instruments come with a small strap that can be used to connect guard to low. Make sure that the strap is in place if you are not making any other guard connection.

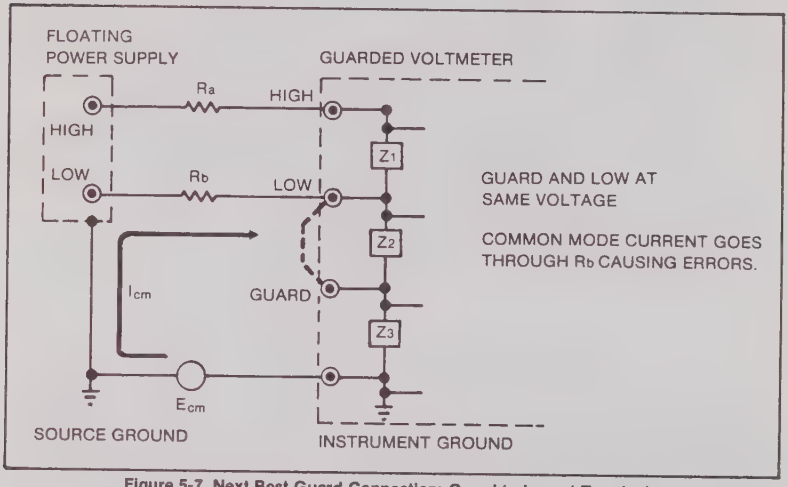


Figure 5-7. Next Best Guard Connection: Guard to Low at Terminals

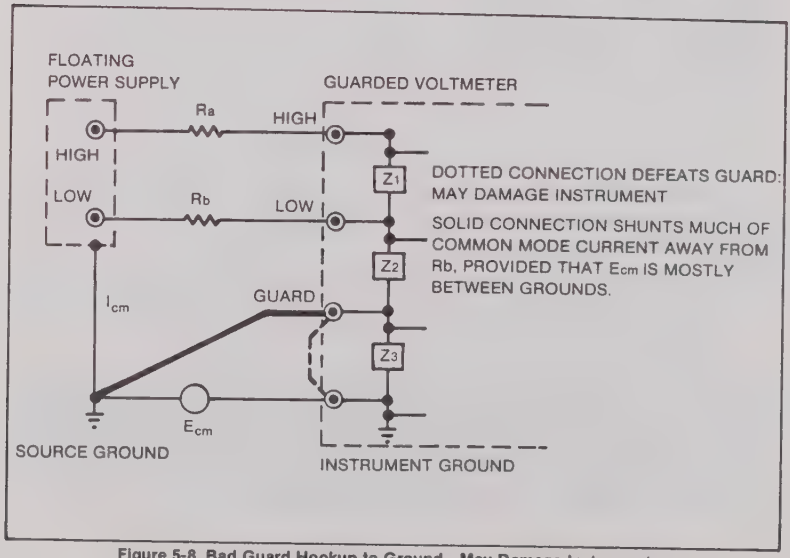


Figure 5-8. Bad Guard Hookup to Ground - May Damage Instrument

Noise Rejection Specifications

Some noise is always present in even the best system design. Therefore, select system components at least partially based on their noise rejection specifications. Normal-mode rejection (NMR), and common-mode rejection (CMR) are the two basic specifications for noise rejection.

Normal-mode rejection (or just noise rejection) is a measure (in dB) of the ratio of the normal-mode noise signal, to its resulting effect on the measured value or readout. Normal-mode noise rejection is achieved by using filters (as shown in Figure 5-9) or by applying specific analog to digital (A/D) conversion techniques.

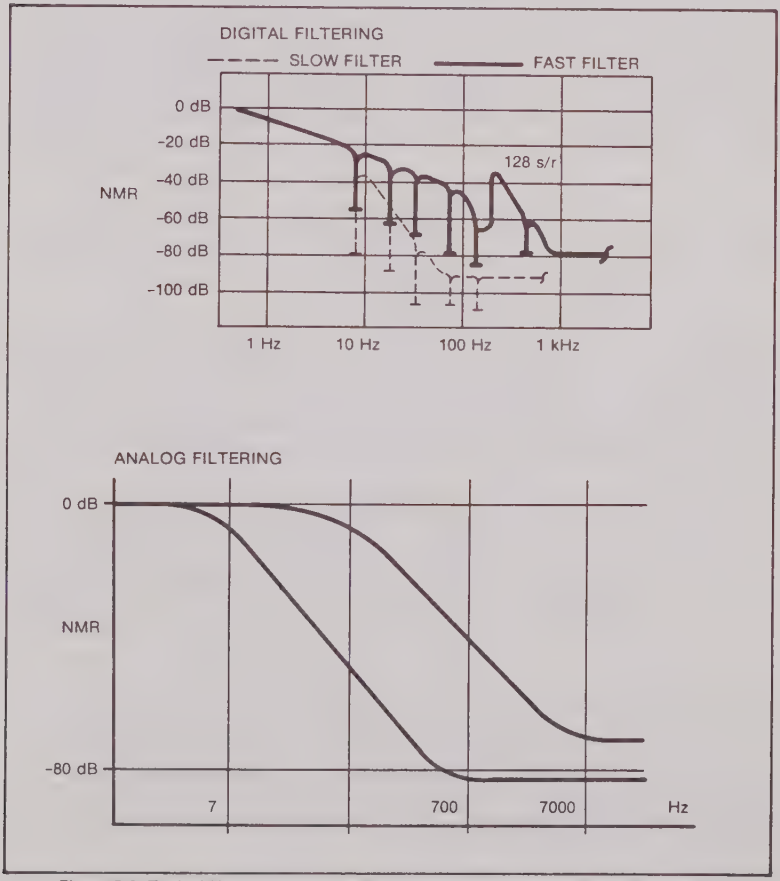


Figure 5-9. Typical Normal Mode Noise Rejection with Analog and Digital Filtering

The normal-mode noise rejection capability of an instrument is always a function of the frequency of the noise. Generally, noise is easier to reject the higher its frequency is relative to the signal being measured. Integrating A/D conversion techniques have high noise rejection at specific frequencies. These frequencies are usually placed to correspond with common power line frequencies (50, 60 and 400 Hz).

Common-mode rejection is a measure of the ratio of the common-mode signal to its resulting effect on the measured value or readout, with a resistive unbalance in the measurement leads (usually 100 or 1000 ohms). CMR specifications sometimes combine both the normal- and common-mode rejection capabilities of the instrument into one specification. CMR is also a function of the noise frequency. Generally, CMR decreases with frequency.

The NMR and CMR required for an instrument to make a particular measurement is a function of the accuracy and resolution required. A thermocouple thermometer with a 0.1 degree accuracy and resolution may need 160 dB of CMR. A 5 1/2-digit multimeter may require 90 dB of NMR. Use the following equation to determine the required NMR and CMR for your measurements.

```
REJ = -20*Log(M_noise/M_nv)
```

Where

REJ = required noise rejection.
M_noise = maximum allowable noise.
M_nv = maximum noise expected.

For example:

If the maximum normal-mode noise expected is 0.1 volt and the maximum allowable reading noise is 10 microvolts,

```
REJ(normal-mode) = -20Log(0.00001/0.1) = 80 dB
```

Or if the maximum common-mode noise expected is 120 volts and the maximum allowable reading noise is 1 microvolt,

```
REJ(common-mode) = -20Log(0.000001/120) = 162 dB
```

Remember that CMR and NMR specifications are always a function of the noise frequency. Most instrument specifications include CMR and NMR ratings at only a few frequencies. A few instruments include a plot of the noise rejection versus frequency in their specifications. Measurement instrument vendors usually do studies of noise rejection versus frequency for each of their instruments, and this information is sometimes available by special request.

Shielding Cables

The one system component that affects noise performance most is the various cables that interconnect the system. Proper shielding in the cables that carry signals around the system is a critical design parameter. Analog signal-carrying cables must be shielded to preserve the various parameters of the signal (voltage, current, frequency, phase, etc). Digital signal-carrying cables must be shielded to ensure the integrity of the communications. Both kinds of cables must be shielded to prevent noise from propagating through the system to a place where it may cause a problem.

Braid, wrapped wire, and foil are the three standard cable shield types. Braid shields are made of groups of fine wire strands braided around the signal-carrying wires. The main advantage of braid is its flexibility and flex life. The tighter the braid, the better the shielding, but tight braids reduce flexibility. Braided shielding works better than other shielding types at low frequencies. It also has a lower dc resistance than foil shields. The dc resistance of the shield is important if the shielding is also serving as a ground return conductor and is carrying a significant current.

Wrapped wire shields consist of wire wrapped in a spiral around the signal-carrying wires. This type of shield has better flexibility and flex life than either foil or braid, but is useful only in the audio frequency range, because the spiral wrap has high inductance.

Foil shields consist of metal foil wrapped around the signal-carrying wires. The foil is usually bonded to a plastic sheet to add strength and insulation. Foil shields have the best coverage of all the cable shield types. They tend to be less flexible than braid and wrapped wire shields. They also have higher dc resistance and lower mechanical strength than other shield types. Foil shields are more effective than braid or wrapped wire in the radio frequency ranges.

Combination shields use two or more shield types over one another to provide shielding that is highly effective over the entire frequency range. Foil/braid shields are common. They combine the 100% coverage and high frequency coverage of foil with the strength and low dc resistance of braid. However, combination shields reduce cable flexibility and tend to be expensive.

SOFTWARE DEVELOPMENT AND OPERATING ENVIRONMENT

Software is often developed in a different environment from where it is to operate. To the software developer, large computer systems offer many advantages over small systems. The computer that is embedded in the system may lack the facilities and tools necessary for developing the required software. In these cases, a host system (see Figure 5-10) may be used to develop software for the target system (the computer embedded in the system). In any case, successful software development requires the use of development tools. The term used for this set of tools is the software development environment.

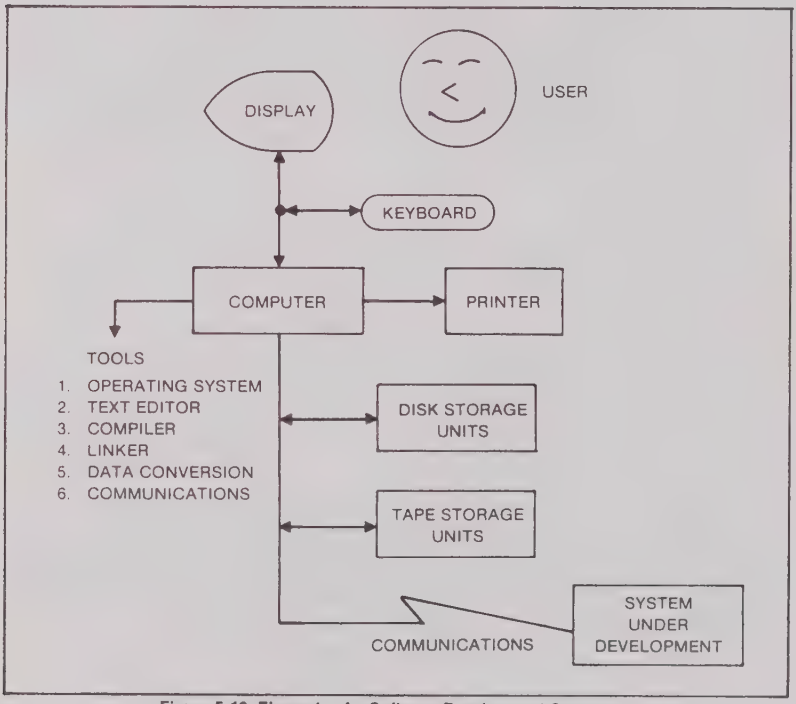


Figure 5-10. Elements of a Software Development System

Software development environments consist of tools that are themselves software packages that run on a computer. As was stated above, the development environment may not be on the same computer as is used in the system. Most development environments contain such tools as compilers, interpreters, assemblers, linkers, text editors, data base managers, scheduling tools, electronic mail, and format conversion utilities. These tools are described later in this section.

In addition to the software tools, software developers need the following hardware tools:

1. A video display terminal.

2. A place to store programs while they are being developed (usually a disk memory system).

3. A place to archive copies of the software (usually a floppy disk or magnetic tape system).

4. A printer for hard-copy listings of the programs.

5. A communication link between the development environment in the host and the target computer in the actual system.

Most modern system software is written in a High Level Language (HLL) like BASIC, ATLAS, FORTRAN, Pascal, etc. Computers, on the other hand, execute low-level languages called machine languages. A main tool in any software development environment is a software package that translates HLL programs into machine language. This tool is called either a compiler or an interpreter. Compilers translate HLL programs into machine language for later execution. Interpreters, on the other hand, translate HLL programs into machine language at the time the program is run.

Interpreters are convenient tools to aid in developing system software because changes to the software can be made quickly (see Figure 5-11). The interpreter usually includes text editors and debugging aids within one package. This means that you can change the software and immediately execute the program. However, interpreted languages tend to be less effective than compilers when large software packages are being developed. This is because it is difficult to modularize interpreted code into small pieces. Modularity is an effective technique for creating complex software designs. Interpreted software is also usually less efficient in the use of computer resources than compiled software. This means that interpreted code usually runs slower than compiled code in the same application.

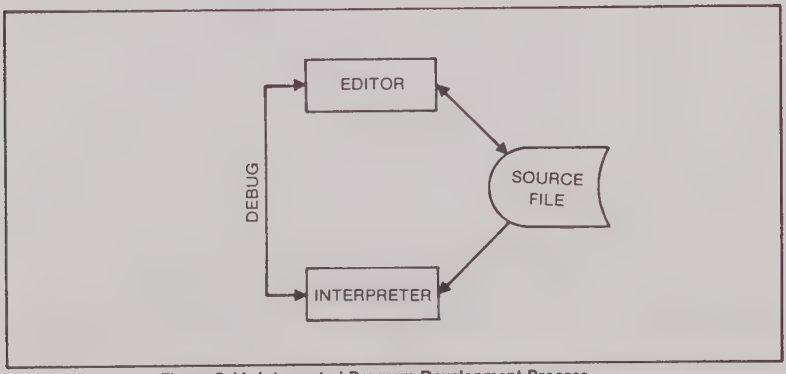


Figure 5-11. Interpreted Program Development Process

Compilers are effective tools when medium to large software packages are to be developed. However, they are a little less convenient to use than interpreters because every time a change is made, the software must be recompiled before it can be run (see Figure 5-12). Also, it is more difficult to debug compiled than interpreted code. This comes about because in compiled code there is no longer a one-to-one relationship between the code that the programmer writes and the machine language executed by the computer. This makes it more difficult to find the exact place that is causing the error. Most compiled language systems include a debugging aid package along with the compiler to make the task of debugging software easier.

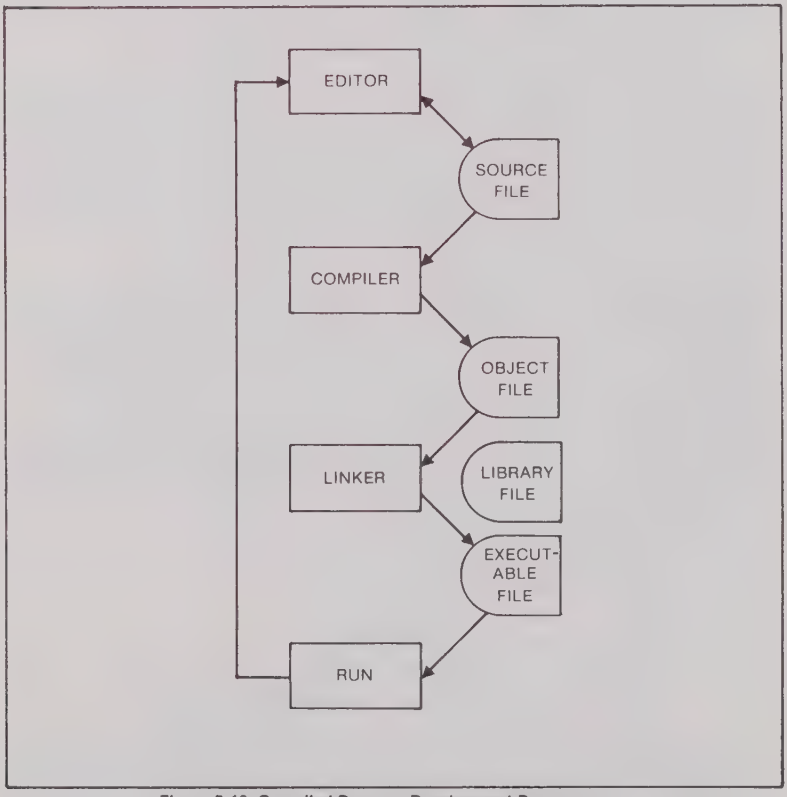


Figure 5-12. Compiled Program Development Process

System builders do not usually have to resort to machine language when writing software. The types of tasks where machine language coding should be used are: when interfacing foreign devices with a computer system, when trying to achieve the maximum software efficiency, and when interfacing with existing machine language software.

An assembler is a tool used to make the task of programming in machine language a little less difficult. Assemblers translate a symbolic representation of machine language into machine language. Language produced by an assembler maintains a one-to-one relationship between the symbolic or assembly code and the machine language.

Symbolic assembly languages tend to be based on mnemonics for the operation to be done, i.e., "ADD A,B" may mean add the contents of the "A" register to the contents of the "B" register and place the results in the "A" register. Programming in assembly language is a low productivity activity and should be reserved for those sections of software where the need is great or where no other technique is available.

A linker is a software package used to join separately compiled or assembled sections of software. Linkers are usually found coupled with compilers or assemblers (see Figure 5-12).

The linker is sometimes an integral portion of the compiler, and the user is not aware of its existence. Linkers are useful because they allow the software builder to produce code broken up into many short sections or modules. A program built up from several small modules of code tends to be more maintainable than one large program. Linkers also allow the software desinger to maintain libraries of software modules that have specific functions. These libraries are then linked with each new program. In this way, the software builder does not need to recode these library functions every time they are needed in a new program. Most compilers come with one or more libraries of vendor-supplied utility function programs. Much time and effort can be saved by making use of such utility libraries.

A text editor is an essential tool for a modern, productive software development environment (see Figures 5-11 and 5-12). This tool does just what its name implies; it allows the user to enter and change the text stored in a computer file. Many varieties of text editors exist. Some of the most complex have some knowledge of the language being entered or changed, so that when a mistake in typing is made, it is flagged to the user immediately. Others have word processing capabilities, so they can be used for both software and documentation work. The choice of a text editor is a personal thing. Everyone seems to have a favorite set of features. Any text editor must allow you to enter and change the text in a file in a productive way. Any features beyond this are strictly a matter of personal taste.

Data base managers are software packages used for maintaining and accessing large accumulations of data. If your system definition includes the storage, maintenance, and manipulation of large amounts of data, you should consider the use or development of a data base manager.

If the system being developed is large or involves several interrelated tasks, you may want to consider the use of a schedule management tool. This tool is usually based on either the PERT or CPM method of scheduling or may combine both techniques. The use of a schedule management tool makes maintaining project schedules much less labor intensive and allows closer tracking of the development project.

Electronic mail is an efficient way for members of a design team to communicate with each other. Paper communication tends to be formal and uses up valuable time and resources. Phone communication depends on a person being at a particular place at a particular time. Meetings take much time and may involve information that not everyone in the meeting needs or should have. Electronic mail, on the other hand, tends to be informal, addresses only the necessary information, and is sent and read at the user's convenience. Electronic mail is available on many computer systems. It is especially effective when people work different hours or are separated from each other by distance or time zones.

Format converters are sometimes necessary when developing software on one system for execution on another. Often the target system expects the programs to be loaded in a different form from what is generated in the the host system. In these cases, a format converter program is needed, either in the host or target system. The vendor of either the host or the target system can usually supply this software to system developers.

DATA MANAGEMENT

Data management is a critical job done by computer-based systems. Data originates from measurements, operator inputs, and communication with other systems. Data is output to the control outputs of the system, to the operator by way of the user interface, and by communication to other systems.

In most systems, data is processed in some manner after it is received. Data is also stored by the system, printed on printers, output in graphical form on chart recorders, and so on. Data management is the term for the entire task of getting the proper data into the system, processing it, and routing it to the proper destination.

Design the data management process before starting the implementation of the system. The data flow within the system should be described as a part of the detailed block diagram of the system. Sources of data should be identified and the format of the data, as received by the system, should be documented. The destination and format of each datum output by the system should also be described. Any necessary data conversion should be included in the detailed design of the system. For example, the mathematical equation necessary to convert the voltage input from a current sensor to the current it represents should be documented in the system design.

During the design of the data management process, be sure to identify any critical timing situations. For example, say a group of inputs are to be checked against limits and the results updated every 10 seconds. Documenting this type of critical function during the design phase will affect the choice of system components and how the system is implemented. Once the system components are chosen and implementation has started, it is too late to consider this type of critical timing.

Another issue to address now is data coherency. In some situations, especially in a computer program where interrupts are processed, data can be updated and used by several different sections of the program. If one section of the program is using some data, and another section of the program modifies the data while it is being accessed, you can get incoherent data.

For example, a program segment may be updating the operator's interface with data from readings taken at 1:00 p.m., just as the 1:10 p.m. readings become available. If the reading data is updated as it becomes available, the operator may see a set of readings marked as being from the 1:00 reading, while some of the data may be from the 1:10 readings. Sometimes, this would cause no harm, but other times it may mislead operators or cause erroneous control outputs. Sometimes, data that is stored in more than one location in the computer memory (floating-point numbers, long integers, etc.) can be partially read at the time they are updated. This is a most serious situation, because the value of the data may be appear to be different from what it really is.

Designing the data flow will help identify those areas where data coherency may be a problem. The standard technique for avoiding this problem is to use of flags, sometimes called semaphores. When a section of a computer program is reading or writing a section of data, it sets a flag so that no other section may have access to the data. All sections of the program must check the status of the flag before accessing the data.

In the example given above, the operator's interface program segment would check the reading semaphore before using the data. If the flag was not set, it would set it and start to use the data. At 1:10 p.m., the new readings become available. The reading update section of the program would have to wait until the reading semaphore is cleared by the operator's interface segment before updating the data. In this way, the data for the 1:00 p.m. reading remains coherent while the operator interface is updated, even though new readings are available.

Loss of data coherency is a common problem in in multi-tasking operating environments, and in computer programs that handle real time interrupts (for example, IEEE-488 Bus SRQ processing, time of day interrupts, and so on). Be especially careful to design the data flow properly in these types of environments.

APPLICATIONS PROGRAMMING

Developing applications software is a major part of the system development task. Applications software and installation are sometimes the only major elements that need to be added to a system to make it application-specific. The software is the heart of a computer-based measurement and control system. If the software is done poorly, the system may fail in its mission.

Doing applications programming correctly involves following these steps:

Each of the steps must be planned and documented. A review should be held at the transition from each step to the next. If a change is made that affects documents from preceding steps, the affected documents must be updated to reflect the change. If the changes are major, they should be reviewed before being implemented.

The aim of all this is to produce a maintainable software package. A package that contains sections that are not described in the documentation is not maintainable. Software maintenance may consume as many resources over the life of the package as it took to get to the release point, so it is important that this function be supported by as many tools as possible. Documenting the software during the development cycle is the most effective maintenance tool available.

The definition of a system is extensively covered in Section 2 of this book. Detailed software design techniques are covered in Section 7. Implementation is covered in Section 8. Test techniques and the release step are covered in Section 9. Maintenance issues are in Section 11. General applications software design is covered next in this section.

DESIGNING AN APPLICATIONS SOFTWARE PACKAGE

The design of the applications software package for a system should proceed naturally from the system specification. The specification should be reviewed, and the functions that will be implemented in application software should be identified. These extracts from the system specification should form the highest level design of the applications software. The detailed design of the software package should proceed from this point.

Structured design techniques are a powerful tool to use at this stage of the software design. This technique dictates a top-down, modular design approach. This technique is covered in Section 7 under Detailed Software Design. Flowcharting is another commonly used technique for detailed software design. However, it has been shown that structured design using hierarchy charts and a Program Design Language is a more productive technique than using flowcharting.

Whatever technique is used to do the detailed software design, it must bridge the gap between the high level information presented in the definition, and the actual code that implements the software package. Don't ever assume that the code can serve as this information bridge. If you do, the programmer will be the only one able to maintain the software. And, after a few months or years, even the original programmer will not be able to remember enough about the package to provide effective maintenance.

DESIGN REVIEW

The detailed design of the system should be reviewed before proceeding into the implementation phase. This review should consist of two parts: an internal review by the members of the design team and a formal review by management.

Each person's design should be reviewed by another knowledgeable person, who should be another member of the design team. If this is not possible, a person who is knowledgeable in the field of the designer should do the review. This review should be held in a non-hostile environment, with the reviewer pointing out oversights in a non-threatening way. The reviewer should not be reviewing the performance of the designer.

Management should not participate in the internal review. The highest level of management included should be the project leader or manager. The reason for this exclusion is that when higher levels of management are involved in a design review, the designer may feel that his or her performance is being reviewed rather than the design. This leads to a hostile environment during the review and defeats the purpose of an internal review.

The formal review is held to communicate to higher management that the design team is making satisfactory progress toward building a system that satisfies the specification. The details of the design itself are rarely reviewed during the formal review. This review is usually attended by upper management and the project manager or leaders. The individual designers may be called in to give supporting information, but they are not the prime presenters at the formal review.

The Specification, Detailed Definition, and Detailed Design documents should be presented to management at the formal review. Management determines from this evidence whether the design team is ready to proceed into the implementation stage. Weaknesses identified during this review should be fixed and a report should be made to a follow-up review before management gives formal permission to proceed into the implementation stage.

The reason for the detailed level of review at this stage is that most of the cost of a systems project is incurred from the implementation stage onward. A design weakness identified during the design review doesn't cost much to fix. Flaws implemented in the design will cost much more. Fixing such problems late in the development process may involve replacement of equipment and implementation changes, as well as redesign time. Less than one-third of the total cost of a system is incurred before the design review.

SECTION 6

SELECTING SYSTEMS COMPONENTS

CONTENTS

Introduction 6-1
Support of Communication Techniques 6-1
Rack System 6-1
Environmental Considerations 6-1
Software 6-2
Systems Multimeters 6-3
Counters 6-5
Signal Generators 6-6
Calibrators and Standards 6-7
Switches and Switch Controllers 6-10
Programmable Power Supplies 6-12
Instrument Controllers 6-12
Terminals 6-13
Automatic Test Equipment (ATE) 6-14
    Component Testers 6-14
    Board-Level Testers 6-15
    Functional Testers 6-16
    Field Service Equipment 6-18
Thermometers 6-18
Data Loggers and Computer Front Ends 6-20

INTRODUCTION

Many devices for modern test, measurement, and control systems are available in component form from commercial vendors. Commercially available system components are much less expensive to use than custom designs. The system builder who uses the component approach can often build a system without actually building any of the hardware.

This section discusses the issues that the system builder needs to address when selecting components to implement a system that has been defined. Substantial definition work should have been done before the system components are selected. Select the components to fit the definition, rather than the other way around.

SUPPORT OF COMMUNICATION TECHNIQUES

One of the first issues to address is how the various components within a system are to communicate with each other. Adding communication capability to a commercial system component can be difficult or impossible. Choose the technique first, and then select components to support the chosen technique.

The details of several digital communications techniques are discussed in Section 7. Design issues relating to communication techniques are addressed in Section 5. Review these sections before deciding on a communications technique. Once a set of techniques is chosen, make sure that each of the potential system components support the necessary technique.

RACK SYSTEM

The mounting system for the instruments in an electronic system is usually some form of rack. Racks come in various sizes and shapes and are available from many different manufacturers. Racks for the system should be selected on the basis of the size of the system elements, the amount of heat generated by the electronics, and the environment in which the system has to operate. The details of rack systems are addressed in Section 7.

ENVIRONMENTAL CONSIDERATIONS

By this stage in the system design process, the system builder should know the exact physical environment in which the system will exist. The choice of the system components and rack system should be made with this environment in mind. Environmental tolerance specifications should be available for each potential system component. The specifications usually include a temperature and humidity range over which the device will operate. Altitude, air flow, dust, noise, liquid submersion depth, and other environmental specifications may also be included.

Make sure that each of the potential system components will operate correctly in the anticipated environment. In a harsh operating environment, it may be more practical to mount the system components in a rack and enclosure system, rather than getting instruments and computers that can exist in an open-shelf environment.

Make sure that enough cooling air reaches each system component inside the rack. Many system components have vents or fans on the sides, top, bottom, or front of the case. These should not be blocked when the device is mounted in the rack. Read the mounting instructions for each component before using them in the rack.

Check the cooling air capacity for each device mounted in the rack, then make sure that the rack or cabinet can supply that much air. You may have to add fans or other such aids to the rack to supply enough air (see Section 7 for more details on cooling).

Make sure that the electrical power distribution to the system components is sufficient. Check line power, voltage, and frequency requirements for each device. Make sure that the sum of all the power requirements for the system, at worst case conditions, does not exceed the supply capacity. The line power supply for a system should be over-designed. Most systems grow a little over time, and having excess line power capacity will allow system components to be added without expensive modifications to the line power supply.

Check the line voltage and frequency for each of the countries in which the system is to operate. In many countries, the line voltage is between 200 and 250 volts and the line frequency is 50 Hz. Make sure that each system component can operate over this range of voltages and at this frequency if the system is to be used in these countries.

CAUTION

> On many devices, there is a line voltage switch that must be in the position that matches the local voltage. Make sure that these switches are in the proper positions or damage to the devices may result.

Compare the noise rejection specifications (see Noise Sources and Solutions in Section 5) for each of the potential system components. Select components with higher noise rejection specifications when a harsh noise environment is expected.

SOFTWARE

Software can be treated as a system component. Software packages are available from system component vendors and many other sources. If a package exists that does something close to what you want to do, be sure to consider using it instead of building your own.

Be sure to choose a reputable vendor for your system software. You will usually be completely dependent on the vendor for maintenance of or upgrades to the purchased software package.

SYSTEMS MULTIMETERS

Systems multimeters (see Figure 6-1) are used to measure voltage, current, and resistance. A multimeter is usually the primary measurement device in any test and measurement system. Systems multimeters have communications capability either built-in or as an option. IEEE-488, RS-232-C, and parallel binary communication interfaces are common among systems multimeters.

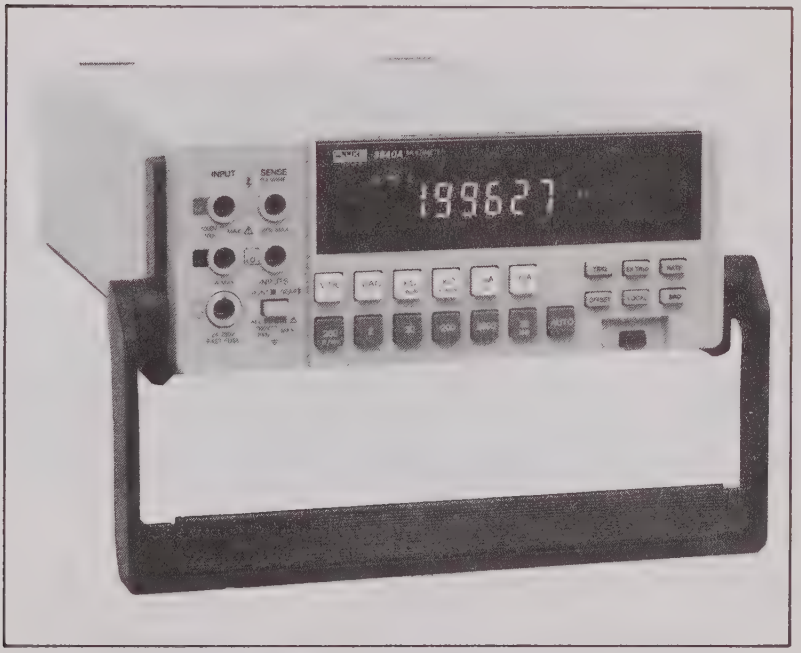


Figure 6-1. Systems Multimeter

Multimeters are characterized by their measurement resolution and accuracy. Resolution is a measure of how small a difference in the parameter to be measured can be detected by the instrument. Accuracy, on the other hand, is a measure of how well the instrument performs in relation to international standards of measure. An instrument may have higher resolution than accuracy.

Modern systems multimeters are usually characterized by the number of digits they can accurately resolve. A 3 1/2-digit meter can resolve readings between -1999 and +1999 units. For example, a 3 1/2-digit multimeter in the 20-volt range will resolve readings between -19.99 and +19.99 volts.

Other than reading resolution, the most important multimeter specification is accuracy. Accuracy is usually specified as a percentage of the reading, plus or minus a number of counts or digits. For example, a 3 1/2-digit meter with a .5% + 2 count spec on the 20 volt range will have an accuracy better then .27 volts when measuring 5 volts (5 x .05 + .02).

Most systems multimeters have isolated measurement terminals. This means that the low measurement terminal is electrically isolated from the instrument ground. Measurements on signals that have high common mode voltage levels can be done using isolated measurement techniques.

Other common specifications or features for multimeters are defined below.

Autoranging
The capability to automatically change to the most appropriate measurement range for the amplitude of the input signal.

Autozero
Residual voltage, current, or resistance errors near zero are automatically corrected without a front panel control.

Burden Voltage
Voltage drop across the input terminals when measuring current.

Common-Mode Rejection (CMR)
The measure of an instrument's ability to measure a signal in the presence of an unwanted common-mode voltage. CMR is usually expressed in decibels (dB).

Crest Factor
Ratio of the peak value of an ac signal to its rms value.

Four-Terminal Ohms
A method for making accurate low resistance measurements where the current source and voltage measurement terminals are separate (also called a Kelvin connection).

Guard
A shield between the measurement terminals and the instrument ground.

Normal Mode Rejection
The measure of an instrument's ability to measure a dc signal in the presence of an unwanted ac signal.

Overrange
The capability of an instrument to measure beyond a range without having to change to the next higher range.

Temperature Coefficient
A factor that shows how the ambient temperature may affect accuracy.

COUNTERS

Counters (see Figure 6-2) are used to measure the frequency and period of ac signals. Counters are also used to measure time intervals and to count (totalize) events. Frequency is usually measured by counting the number of full cycles of the input signal over a specific time period (gate time). Period is measured by counting the number of cycles of a fixed frequency signal during a specific number of cycles of the input signal. Time interval measurements are a variation of period measurement. A totalizer function counts the number of events (either a positive or negative signal edge) that have occurred since the total was initialized.

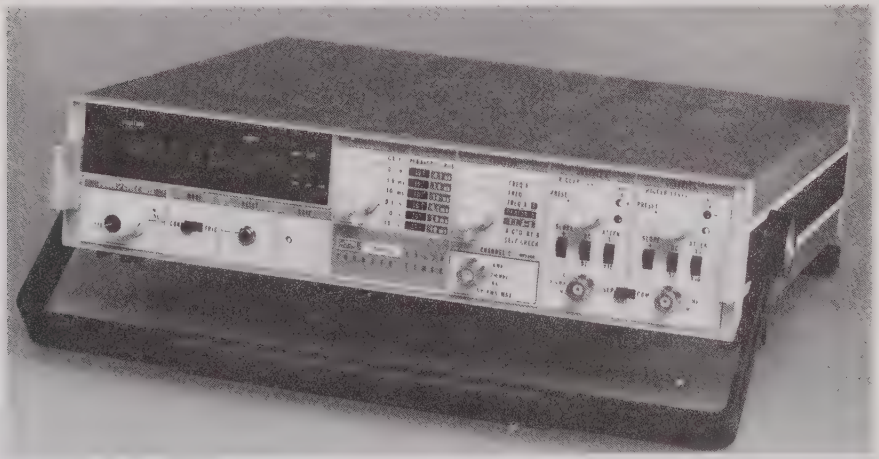


Figure 6-2. Frequency Counter

Counters are characterized by their useful frequency range, measurement resolution, and accuracy. Other important parameters are the trigger sensitivity, input impedance, and whether ac or dc (or both) coupling is used.

The maximum frequency that can be measured is the most important specification for a counter. This specification tells you whether the counter is suitable for your application. In general, a counter has several ranges. Each range has a specific measurement resolution and gate time. The lower the frequency, the longer the gate time has to be to achieve a specific resolution. Because of this, some counters use period measurement techniques to measure low frequencies.

The accuracy of a counter is determined by the accuracy and stability of its time base. The time base generates the gate signals used in frequency measurement and the fixed frequencies used in period and time-interval measurements. Some counters allow an external time base to be used with the instrument. The accuracy of frequency measurement within a system can be increased by using a precision time base to feed all the frequency measuring instruments.

Trigger sensitivity is an important specification when weak or noisy signals are to be measured. If the trigger sensitivity is too low, a weak signal may cause the instrument to skip some or all of the signal's cycles. This can cause erroneous or faulty measurements.

Many frequency counting instruments have non-isolated signal inputs (the low terminal is directly connected to the instrument ground). This makes the instrument difficult to use in measuring signals that have large common-mode voltage levels. Make sure that using a counter in a test or measurement system will not cause common-mode current problems because of the non-isolated inputs on the counter.

SIGNAL GENERATORS

Signal generators (see Figure 6-3) are used to generate ac signals of variable frequency, amplitude, and modulation. Signal generators should be chosen on the basis of the frequency range, frequency accuracy, frequency and level stability, modulation techniques, output level range, and spectral purity.

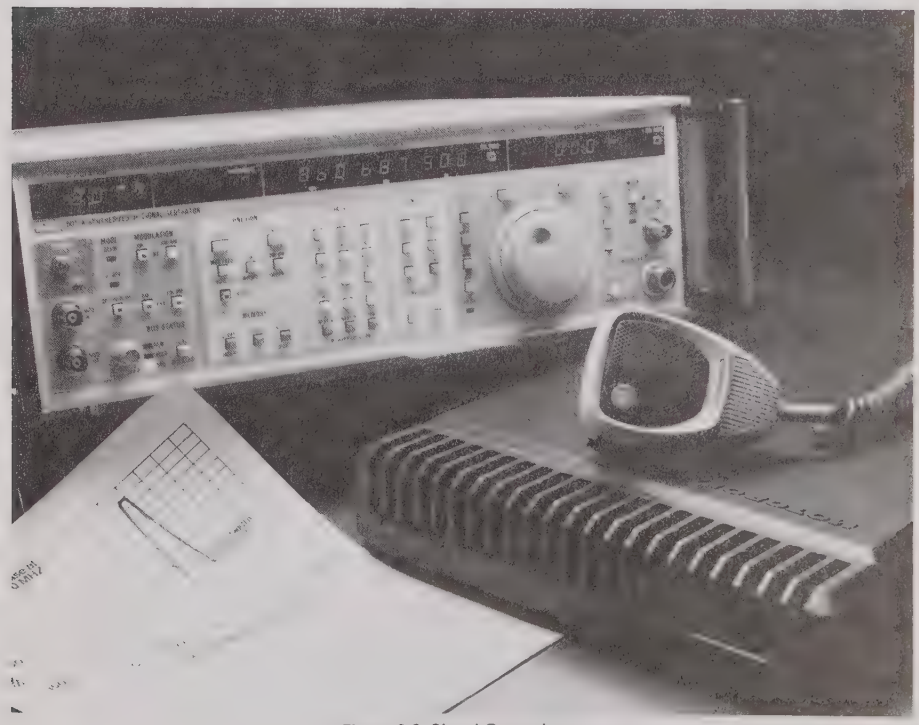


Figure 6-3. Signal Generator

The frequency range specification for a signal generator usually gives both a low and high frequency limit. The frequency setting resolution usually varies with the output frequency. The accuracy and stability of a signal generator depend on the type and quality of the internal oscillator.

Amplitude, frequency, phase, and pulse modulation are the four types of modulation commonly available in signal generators. All signal generators offer one or more of these modulation types. Some of the higher quality generators offer all four types of modulation.

An ideal signal generator would produce a single spectral line in the frequency domain. This ideal is never achieved because of the practical limitations of the devices used. The output of a signal generator consists of the desired signal plus undesired discrete signals and noise. The ratio between the levels of the undesired and desired signals is called the spectral purity of the generator. Spectral purity is generally specified as the level (in dB) that the undesired signal is below the desired carrier signal.

CALIBRATORS AND STANDARDS

Calibration is a special, highly-refined measurement process in which test, measurement, and control instruments of unknown status are compared to well-defined standards of greater accuracy. This comparison is done to detect, eliminate by adjustment, and report any variations in accuracy or capability. Calibrators (see Figure 6-4) are a class of instruments whose primary applications are to calibrate another instrument and to source extremely accurate signals.

Electrical standards establish the rules for measuring electrical quantities. The most common electrical standard is the volt. Other standards define the units of resistance, current, frequency, and temperature.

Traceable calibration means that the standards used in the calibration process can be related to the National Measurement System through an unbroken chain of documented calibration comparisons. The National Measurement System is maintained in the U.S. by the National Bureau of Standards (NBS). Many government or industry standards require the use of traceable calibration techniques.

Calibrators and standards are chosen on the basis of the level of uncertainty that must be achieved during the calibration process.

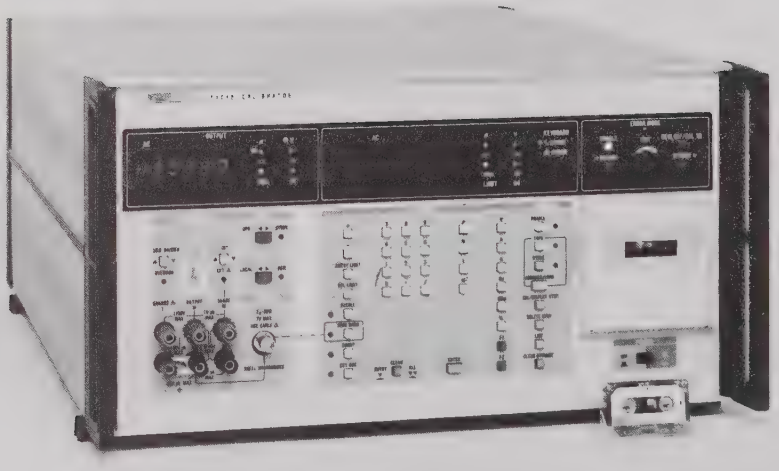


Figure 6-4. Multi-Function Calibrator

The seven recognized standards levels are listed below.

1. **Tertiary Level** Includes instruments used for production work and quality control, for maintenance, and for general measurement purposes.

2. **Local Secondary Standards** Used for calibration work and as references in certain production and engineering areas.

3. **Transfer and Inter-laboratory Standards** Used to maintain or represent the basic electrical units locally; sometimes referred to as Local Primary Standards.

4. **NBS Working Standards** Used to calibrate and certify local standards.

5. **NBS Secondary Standards** Includes Transfer, Check, and Scaling standards. Used to compare NBS Working Standards to the Legal Electrical Reference Units, the values of which are embodied in the NBS Primary Standards.

6. **NBS Primary Standards** Derived from the Basic "SI" Units.

7. **International System Of Units (SI)** The units system that ties the whole standards structure together. This system consists of the following seven units of measure:

   A. Meter: length
   B. Second: time
   C. Kilogram: mass
   D. Ampere: electrical current
   E. Kelvin: thermodynamic temperature
   F. Candela: luminous intensity
   G. Mole: amount of a substance

Each level of instrument must be calibrated by a higher level standard. For example, Tertiary Level equipment should be calibrated by Local Secondary Level equipment, and Transfer Standards must be calibrated by NBS Working Standards. The proper level of calibration should be chosen on the basis of the equipment to be calibrated. It makes little sense for Tertiary Level equipment to be calibrated by Primary Level equipment.

Another consideration when selecting calibration equipment is the environment that can be maintained in the area where the system is installed. The higher standards levels require strict adherence to the environmental constraints of temperature, relative humidity, and main supply voltage regulation.

Many different types of calibrators are used in electronic systems. Calibrators are characterized by the type of signals that they produce. Calibrators are commonly used to to produce accurate voltages, currents, and resistances. Many calibrators produce a combination of several different signal types. For example, a meter calibrator may produce ac and dc voltage, current, and resistance. An oscilloscope calibrator may produce dc voltage, current, low duration pulses, timing markers, and fast rise-time edges.

Calibrators are often teamed with other instruments and standards. Power amplifiers are used to boost the power output of an ac/dc voltage calibrator. Transconductance amplifiers convert a precision voltage, output by an ac/dc voltage calibrator into a precision current. External voltage standards are used to increase the accuracy of dc voltage calibrators.

SWITCHES AND SWITCH CONTROLLERS

A system switch (see Figure 6-5) routes analog signals to their proper destinations within a system. Scanners and matrix switches are two standard types of switch units used in electronic test, measurement, and control systems. Several units combine the functions of a scanner and a matrix switch. Also, switches are sometimes included as an integral part of an instrument. For example, a data logger combines a measurement device with a scanner.

Figure 6-5. Switch Controller

Scanners are used to switch more than one input channel, one at a time, onto a single output channel. Scanners typically use break-before-make switches, so that the current input channel is disconnected before another channel is connected. Scanners are typically used in measurement and control systems to feed several measurement points into one measurement instrument.

Matrix switches are arranged so a wide variety of connections can be made between several inputs and outputs. Matrix switches often use latching switches to maintain the configuration of closed and open switches while the test is running. Matrix switches are used in test systems to route several measurement and stimulus signals to and from the instruments in the system and test points connected to the Unit Under Test.

There are several types of switches used in scanner and matrix switch units. The most common part is the electromechanical relay. Other switches use Field Effect Transistors (FETs) and other semiconductor devices. Electromechanical devices are slow, subject to wear, and take up much space. However, they offer lower resistance when they are activated than semiconductors do, and they can switch high voltages (up to several hundred volts). They also offer the best channel-to-channel signal isolation and voltage standoff.

Semiconductor switches, on the other hand, are fast, but cannot handle voltages over about 40 volts. They have poor channel-to-channel signal isolation and have high resistance when they are turned on. The most significant problem with semiconductor switches is that they have poor voltage standoff. A high voltage spike or surge on a channel that is not even being sampled may cause noise problems in the system or may even damage the switch and other system components.

When using switching devices to switch thermocouples and other low voltage output devices into measurement devices, the switch unit must have a low thermal offset specification. Switches can insert small voltages into the measurement lines. This is because of temperature differences between one switch and another. Low thermal offset switches are designed to minimize temperature differences between switches in a channel.

Another issue that must be addressed when selecting a switching device is the number of lines that need to be switched per channel. A normal channel has two (high/low) or three (high/low/guard) lines per channel. However, a resistance channel may have to have four lines. A channel for making a bridge measurement on a strain gauge may have up to eight lines. Be careful to select a switch that meets the needs of each measurement or stimulus hookup.

PROGRAMMABLE POWER SUPPLIES

Programmable power supplies are used to generate selected voltages and currents. They are similar in function to dc calibrators, except that they usually have no external controls, have lower accuracy and resolution, and generate voltages over a more limited range. However, they are usually capable of supplying more power than most dc calibrators.

Applications for programmable power supplies range from providing operating power for UUTs in an ATE system, to providing high power stimulus signals as a part of the test itself. All programmable power supplies have a control interface. Common interface types include Binary Coded Decimal (BCD), IEEE-488, or RS-232-C.

INSTRUMENT CONTROLLERS

Instrument controllers (see Figure 6-6) are computers that are specifically designed for systems use. They differ from general purpose computer systems because their I/O systems, operator interfaces, and languages are optimized for instrument control.

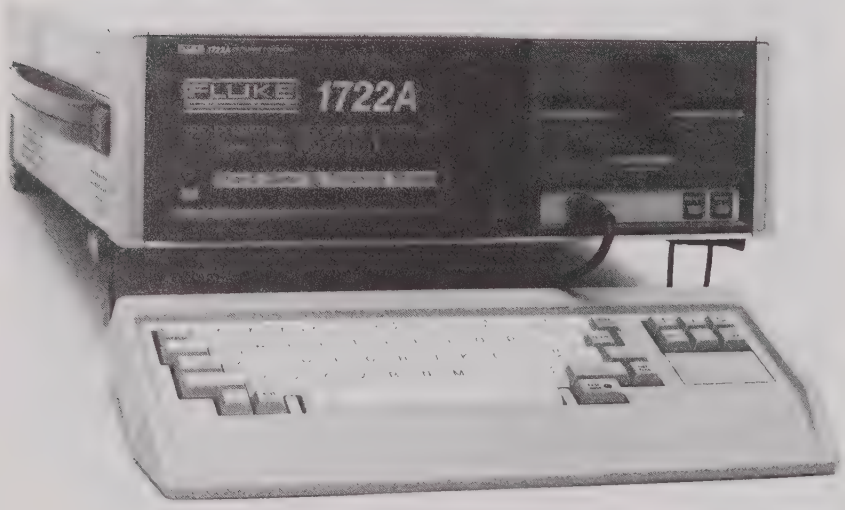


Figure 6-6. Instrument Controller

An instrument control computer is the heart of any test, measurement, or control system. The control computer should be selected on the basis of the following:

1. Capability of executing the system software within the restraints of the system specifications. This should include compliance with the system language, memory size, and timing requirements.

2. Support of the necessary system communications techniques.

3. Support for the operator interface.

4. Environmental constraints (temperature, humidity, vibration, dust, etc).

5. Form factor constraints (such as rack mountability, case size, etc).

6. Enough mass storage for the system data base and programs.

TERMINALS

Video display terminals (VDTs) are used to implement user interfaces to systems. Many instrument controllers contain built-in terminals. However, because of cost, distance, or functional requirements, the system builder may want a terminal that is separate from the system controller.

VDTs should be chosen on the basis of the following:

1. Screen size (size plus number of characters across and down).

2. Color display support if necessary.

3. Support of keyboards, touch-sensitive overlays, light pens, and other input devices.

4. Support for graphics display.

5. Human factors (tilt screen, glare from screen, design of keyboard, character font, etc).

6. Environmental considerations (temperature, humidity, dust, vibration, etc).

AUTOMATIC TEST EQUIPMENT (ATE)

Several types of tests are done in the same way by many different companies. Packaged and configured Automatic Test Equipment (ATE) systems have been developed by several vendors to do these tests. There are four basic kinds of ATE:

- Component testers
- Board level testers
- Functional test equipment
- Field service equipment

These kinds of equipment have several things in common. They all do a specific range of tests on specific types of Units Under Test (UUTs). They all do these tests in a semi- or fully-automatic manner, and they are sold by the vendors as a product rather than as a custom designed system.

Component Testers

Component testers do parametric or Go/NoGo tests on electronic components. There are two basic kinds of component testers: passive and active. Passive component testers are used to test such components as resistors, transformers, inductors, etc. They usually source a dc or ac voltage or current through the component and measure the currents and voltages that result to determine the value of the component.

Active component testers are used to test transistors, integrated circuits, diodes, etc. These testers source voltages, currents, specific waveforms, sequences of digital states, etc, and sense the results. The response of the part under test is compared with an expected response, and the results are displayed or used in a Go/NoGo decision.

In parametric component testing, the aim is to find the value of the component under test. In Go/NoGo testing, the object is to find out if a component parameter is within a specific range.

Component testers are used in electronic component manufacturing facilities as final inspection and test systems. They are also used for receiving inspection by electronic equipment manufacturers. Because of manufacturer's demands, several special types have been developed, including memory testers and microprocessor testers.

Board-Level Testers

Board testers (Figure 6-7) test printed circuit boards, either with parts loaded (in-circuit component testers) or bare (bare-board testers). These testers usually have an array of spring-loaded nails that contact the bottom or top of the board under test. Signals are sourced through some of the contacts and measured through others to test the components loaded on the board and the board itself.

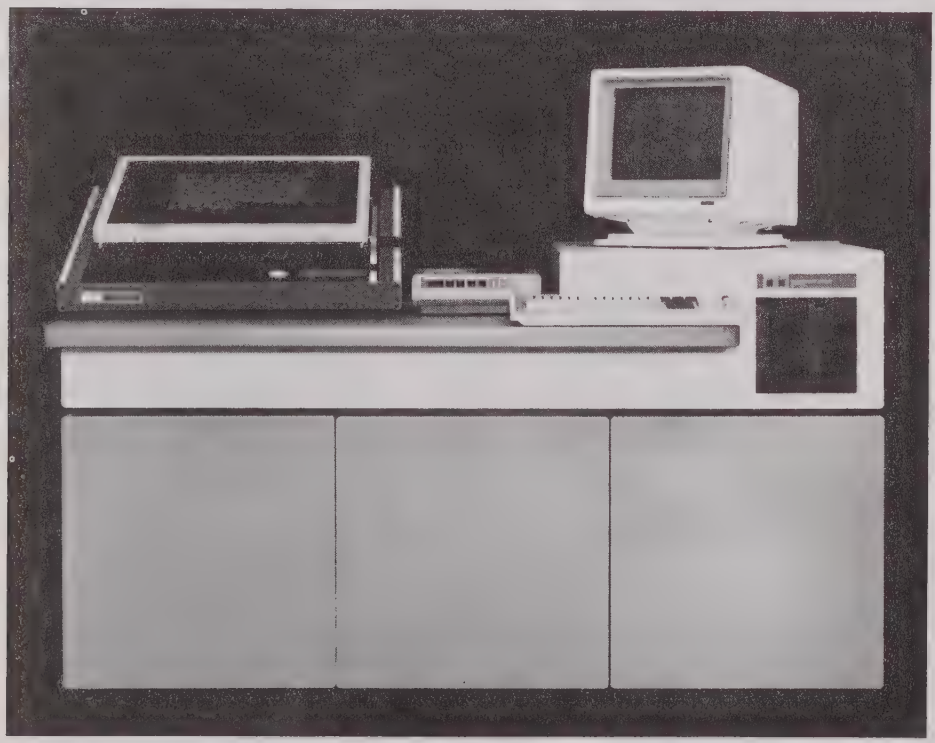


Figure 6-7. Board-Level Tester

Board-level testers test printed circuit boards and assemblies for shorts, opens, bad parts, wrong parts, etc. They can be used to find manufacturing defects. They are rarely found outside an electronics manufacturing facility.

Functional Testers

Functional testers (Figure 6-8) verify that an electronic assembly is operating according to its specifications. Functional testers apply power to the UUT and test to determine if all functions of the UUT are correct. The functional tester usually connects to the UUT via system connectors (card-edge connectors, communications connectors, etc). They force specific voltages, currents, and digital states on the inputs to the UUT, and sense the values and states of the outputs. These responses are compared to a set of expected responses, the responses from a known good UUT, or with the results of a simulation of the UUT.

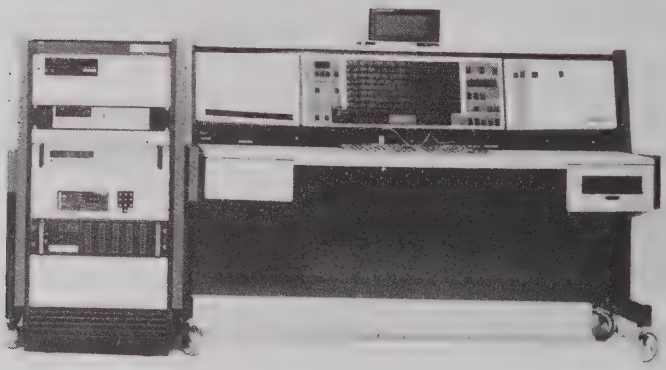


Figure 6-8. Functional Test System

All functional testers flag differences between the responses of the UUT and the expected responses. Some testers support further isolation of the source of faults by using manual or semi-automatic probing of the UUT by the operator.

To perform a functional test on a UUT that contains a microprocessor presents a special case. The existence of a small computer within the UUT causes complications during testing. A new class of tester has been introduced to simplify testing of such UUTs. This new tester is the Fluke Micro-System Troubleshooter (see Figure 6-9). This instrument plugs into the microprocessor socket and allows the system controller to have access to all the signals controlled by the processor.

Figure 6-9. Using a Micro-System Troubleshooter Within a Functional Test System

Field Service Equipment

ATE systems that support field service activities must be portable. Because of this they tend to be smaller and less capable versions of the test equipment found in electronic manufacturing facilities. Field service of electronic equipment is aided somewhat because most equipment that must be fixed in the field operated correctly at some time in the past. This is in contrast with factory test, where the UUT is being turned on and tested for the first time.

Field service concerns itself with troubleshooting a malfunctioning UUT to either the subassembly or part level. Equipment used includes multimeters, oscilloscopes, signature analyzers, and microprocessor-based system testers.

As in functional testing, the UUT that contains a microprocessor presents a special case in field service. The existence of a small computer within the UUT causes complications when troubleshooting the UUT. A new class of tester, the Fluke Micro-System Troubleshooter, has been introduced to simplify servicing such UUTs. The Micro-System Troubleshooter, shown in Figure 6-10, plugs into the microprocessor socket, permitting access to all the signals controlled by the processor. The Troubleshooter runs a series of automatic or user-defined tests to determine if the circuits connected to the processor are the cause of the fault.

THERMOMETERS

Thermometers convert the output of temperature-measurement sensors and transducers, such as thermocouples and RTDs, to a temperature reading for display or systems use. Thermometers are necessary because the output of most temperature transducers is a non-linear, complex function of the temperature being measured.

Thermometers should be matched to the temperature sensor in use. When thermocouples are used as sensors, it is sometimes necessary to match the thermometer to the type of thermocouple in use. Other thermocouple thermometers allow the operator to use switches or jumpers to select the thermocouple type. Another prime selection factor is the accuracy and resolution necessary for the measurement in question.

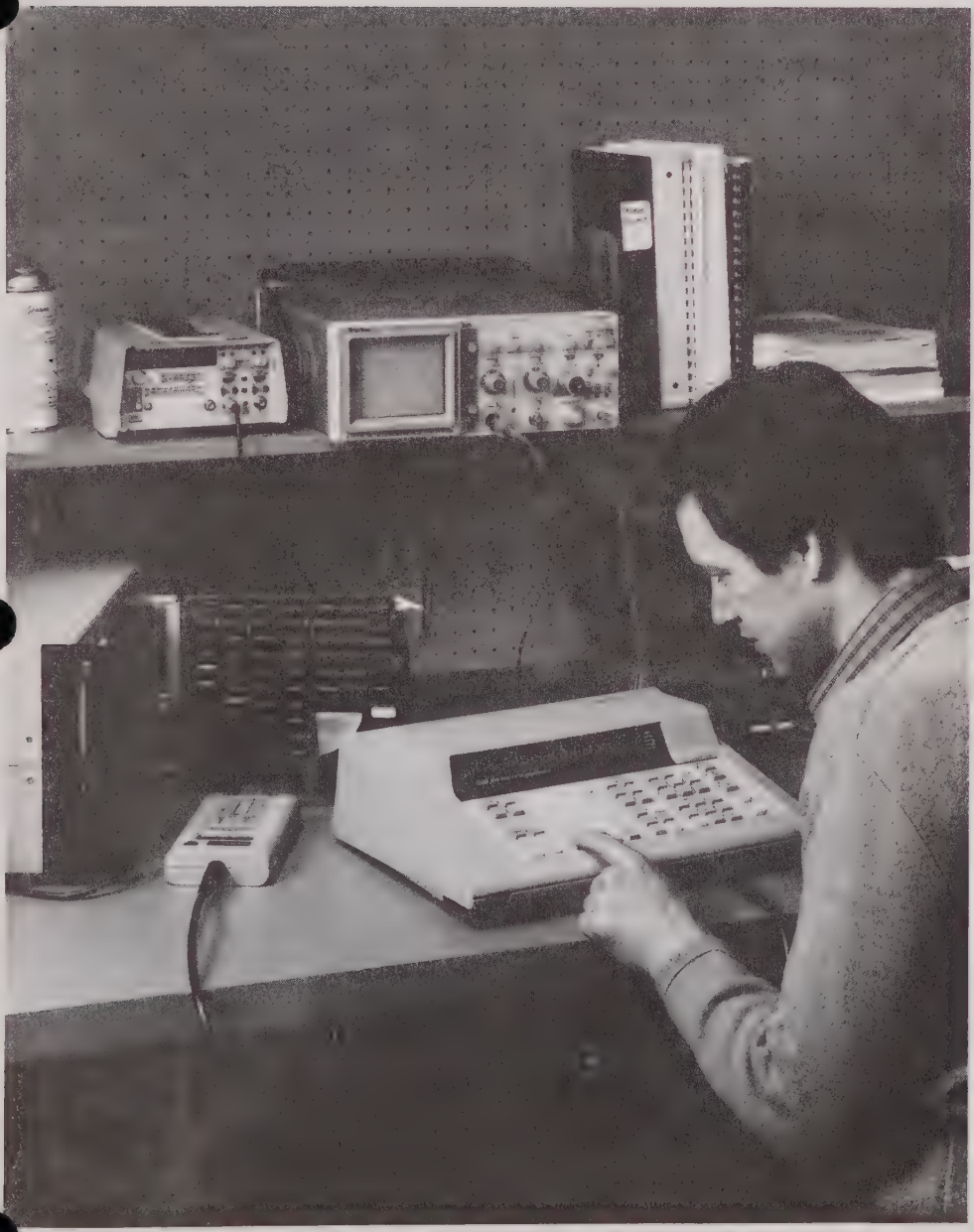


Figure 6-10. Field Service with a Micro-System Troubleshooter

DATA LOGGERS AND COMPUTER FRONT ENDS

Data loggers (see Figure 6-11) are used to acquire, convert, record, process, and communicate information on physical parameters directly to an operator or recording device. Computer front ends do some of the same functions, but communicate the information they gather to another computer. The basic difference between the two classes of instruments is that data loggers are optimized for use by a human operator, while computer front-end instruments are optimized for communications with a computer.

Both instruments combine the functions of a multimeter, thermometer, switch controller, instrument controller, and sometimes a data recorder in one package. Data loggers can be used as stand-alone data acquisition systems or as a system component. The primary function of data loggers is to convert the acquired data into a form that is useful for people. An advantage of a data logger is that the program is entered as a series of keystrokes from the front panel. There is usually no need to learn a programming language to use a data logger.

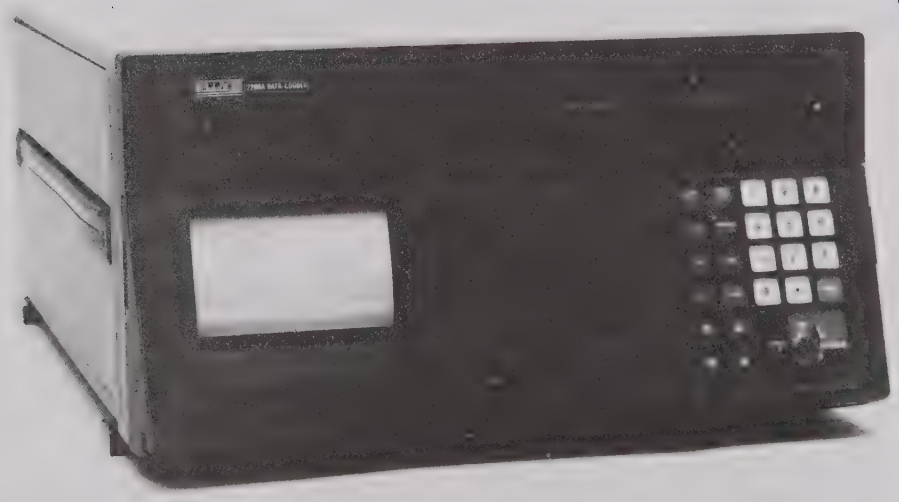


Figure 6-11. Data Logger

Computer front end instruments are used to acquire physical parameters and convert them into a form suitable for computer processing. Intelligent Computer front ends combine data acquisition functions with processing capability. Intelligent front ends can do many measurement and control functions in a stand-alone configuration. Computer front-end devices are programmed in a computer language, usually a form of the BASIC language. By using a front end in combination with an Instrument Controller or other small computer, you can build a powerful data acquisition system in a small space.

A data logger can be used as a computer front end, and computer front end instruments can be used like data loggers. However, using these instruments in this manner is not efficient. If the primary function of your data acquisition system is the accumulation of information for use by operators and other people, a data logger is the best instrument for the application. If, however, a computer is the main user of the data, a computer front-end device is the better choice.

SECTION 7

DETAILED DESIGN CONSIDERATIONS

CONTENTS

Introduction 7-1
Difference Between a Sensor and a Transducer 7-1
Measurement 7-1
- Voltage 7-1
- Resistance 7-4
- Conductance 7-6
- Current 7-6
- Frequency 7-7
- Period 7-8
- Power 7-9
- Temperature 7-9
  - Thermocouple Temperature Measurement 7-10
  - Thermocouple Junctions, Probes, and Wires 7-13
  - Termocouple Measurement Error Sources 7-15
  - Resistance Temperature Measurement 7-15
  - RTD Measurement Error Sources 7-16
  - Semiconductor Temperature Measurement Techniques 7-17
- Strain 7-17

Signal Sourcing 7-22
- Voltage 7-22
- Current 7-25
- Resistance 7-25
- Frequency 7-25

User/Operator Interface 7-28
- Video-Display Terminals (VDTs) 7-28
- Light-Emitting Diode Displays (LEDs) 7-29
- Liquid Crystal Displays (LCDs) 7-29
- Vacuum Flourescent Displays 7-30
- Analog Indicators 7-30

Data Management 7-31
IEEE-488 Bus Communications 7-31
- Benefits of Using IEEE-488 7-32
- Considerations When Using IEEE-488 in Systems 7-34
- Basics of Using the IEEE-488 Bus 7-34
- IEEE-488 Bus Control Computers 7-35
- How the IEEE-488 Bus Operates 7-36
- Bus Control Signals 7-39
- Handshake Control Lines 7-39
- Device Addresses 7-41
- Messages 7-43

Interface Functions 7-46
Data Transfer Control (SH, AH, T, and L Functions) ... 7-46
Source Handshake 7-46
Acceptor Handshake 7-46
Talker and Extended Talker 7-47
Listener and Extended Listener 7-48
Service Request (SR Function) 7-50
Parallel Poll (PP Function) 7-50
Remote/Local (RL Function) 7-51
Device Clear (DC Function) 7-51
Device Trigger (DT Function) 7-51
Controller (C Function) 7-52
Electrical Interface Type (E Function) 7-52
RS-232-C Communications 7-53
Benefits of Using RS-232-C 7-53
Considerations When Using RS-232-C 7-53
How RS-232-C Works 7-54
RS-232-C Signal Definitions 7-57
RS-449, RS-422, RS-423, and RS-485 Communications 7-59
How RS-422 Works 7-60
How RS-485 Works 7-63
Computer Data Networks 7-65
ISO Reference Model 7-65
Network Topologies 7-76
Network Channel Control 7-69
Network Physical Implementation 7-70
Telephone and Other Carrier Systems 7-70
Current Loops 7-71
How a Current Loop Works 7-71
Modems and Multiplexers 7-72
Modems 7-72
How Modems Work 7-72
Baud vs Bits Per Second 7-73
Full- and Half-Duplex Communication 7-73
Synchronous vs Asynchronous Communication 7-74
Modem Standards 7-74
Multiplexers 7-76
How Multiplexers Work 7-76
Software 7-76
Detailed Software Design 7-77
Program Design Language (PDL) 7-79
Rack and Enclosure Systems 7-84
19-Inch Rack Dimensional Standards 7-85
Rack Environmental Standards 7-86
NEC Classes 7-86
NEC Groups 7-86
NEC Divisions 7-86
NEMA Terminology for Enclosures 7-87
Rack Cooling 7-88

INTRODUCTION

This section contains information on the detailed design of systems using Fluke systems components. This information should be used to augment the information given in Section 6.

DIFFERENCE BETWEEN A SENSOR AND A TRANSDUCER

Two of the most misused terms in the systems business are "sensor" and "transducer." A sensor is a device that reacts directly to changes in the parameter being measured. A transducer, on the other hand, changes energy from one form into another. A transducer usually includes a sensor, but is much more. For example, a pressure sensor may consist of two strain gauges mounted on a diaphragm. A pressure transducer may contain the sensor, an excitation circuit, sensitivity and zero adjustments, and a thermal-offset compensation network.

The output of most sensors is a non-linear function of the parameter being measured. Moreover, the output of a sensor is usually a low-level voltage or current signal. Sensors must be used with instruments that are designed for the specific sensor type. This is cost-effective only when many of the same type of sensor are to be used or when instrumentation is readily available, i.e., thermometers for thermocouples and resistance temperature detectors (RTDs).

The output of transducers is a linear function of the parameter being measured. The output is usually a high-level voltage (0 to 50 mV and 0 to 100 mV are common ranges) or current (4 to 20 mA is a standard). Transducers can be used with any measurement device capable of reading voltages or currents within their output range. Many small meters and other devices are optimized for reading and displaying transducer outputs.

MEASUREMENT

Parametric measurement is a primary function of all test, measurement, and control systems. The following paragraphs address some of the types of measurements typically found in such systems.

Voltage

Voltage is a measure of electromotive force. The unit of measure for voltage is the volt. Voltage measurements are common in electronic systems. Not only is voltage itself a common measurement type, but many other parameters are measured as a function of the voltage from a sensor. For example, thermocouples generate a voltage that is a function of the difference in temperature between two junctions in dissimilar wires. A voltage is measured, but the actual parameter is temperature.

Voltage is measured using various techniques. System builders usually do not need to know the details of how the voltage is measured. You do, however, need to determine the accuracy to which the voltage needs to be measured, the resolution needed, the expected range of the voltage, the noise expected, and the rate at which the voltage is to be sampled. When you know the necessary accuracy, resolution, range, noise rejection, and measurement rate, you can choose a voltage measurement device. However, you will find that some knowledge of the common techniques for voltage measurement is useful.

The aim of voltage measurement in systems is to convert the analog voltage into a binary or decimal number. This process is called analog-to-digital (A/D) conversion. It is done so that system elements can treat the voltage as a piece of data in computations, and the value of the voltage can be communicated to the operator and other places where the data is used. Computers and their associated software cannot use the analog voltage, but once the voltage is converted into a number, it can be treated like any other data.

The three most common ways of doing a voltage A/D conversion are: comparison to a known voltage, by integration techniques, and conversion to frequency and counting. The latter technique (see Figure 7-1), uses a voltage-controlled oscillator (VCO). The frequency produced is measured using standard frequency measurement techniques which are discussed later in this section. The frequency produced is proportional to the voltage input to the VCO. This type of A/D is slow and its linearity is dependent on the quality of the parts used in the VCO converter.

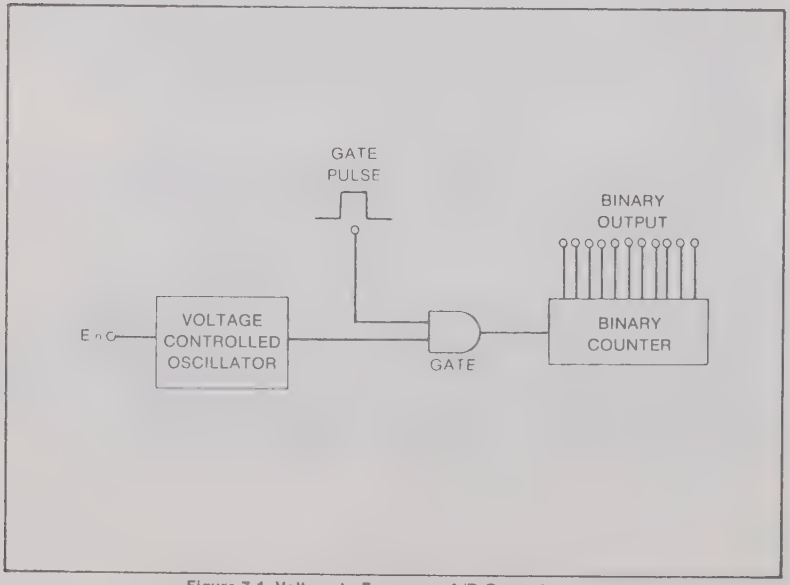


Figure 7-1. Voltage-to-Frequency A/D Converter

Voltage comparison is done in several ways. In one common technique (see Figure 7-2), a variable, known voltage is generated by a digital-to-analog converter (D/A converter). This known voltage is then compared with the voltage to be measured which has been captured by a sample-and-hold circuit. The variable voltage is changed until it is close to the value of the unknown voltage. When the unknown voltage is the same as the known voltage (within the reading resolution of the A/D converter), the reading is assumed to be complete. This technique is as accurate as the resistors, reference voltage source, and switches used in the converter circuit. This technique can be made to be fast; however, noise rejection is low since the voltage is sampled during a short time.

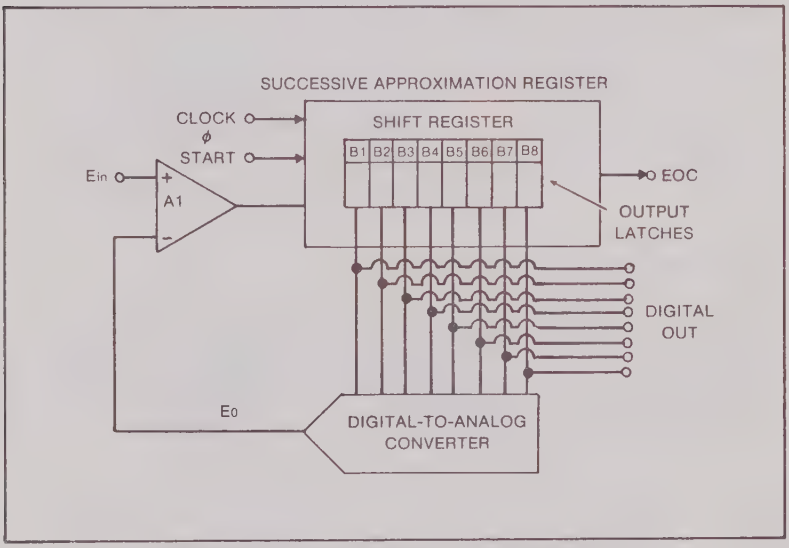


Figure 7-2. Voltage Comparison A/D Converter

In integrating A/D converters (see Figure 7-3), the unknown voltage is integrated over a fixed time period. The resulting value is read by switching a known reference voltage (of the opposite sign from the unknown voltage) into the integrator, and measuring the time necessary to integrate to some fixed voltage level. This technique is known as dual slope A/D conversion. It can be made as accurate as the reference voltages, switches, and integrator design allows. This technique is slower than the voltage comparison technique, but it is possible to chose an integration time that cancels out low-frequency noise.

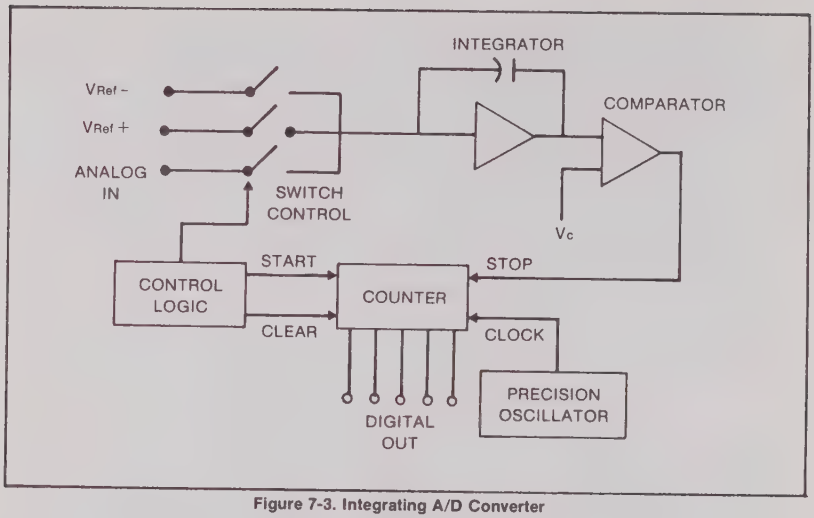


Figure 7-3. Integrating A/D Converter

Resistance

Resistance (R) is a measurement of the property of a conductor that opposes the flow of electricity. The unit of measure for resistance is the ohm. Resistance is almost always measured by forcing a known current through the resistor and measuring the resulting voltage (see Figure 7-4). The resistance is then found by Ohm's law (V=IR, or in this case R=V/I). The voltage is measured using the techniques outlined previously.

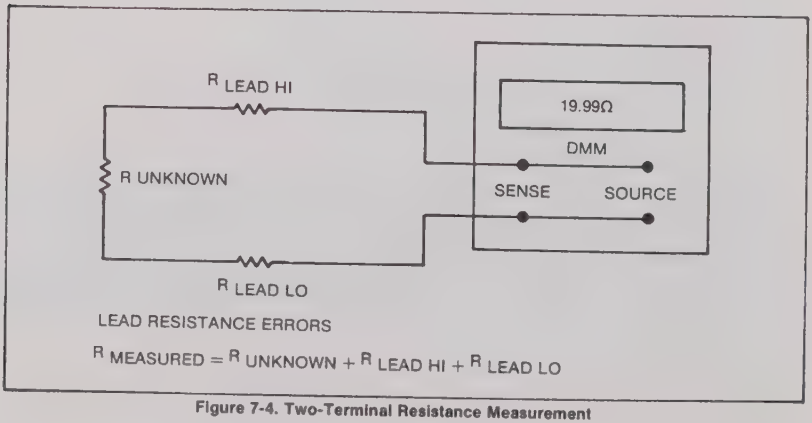


Figure 7-4. Two-Terminal Resistance Measurement

Most devices for measuring resistance contain the current sources, an A/D converter for measuring the voltage, and a device that converts the measured voltage to a resistance value. In computer-controlled instruments, the conversion is done using mathematics.

The resistance to be measured often represents the actual parameter of interest. For example, the change in resistance of a strain gauge is a function of the stress on the material to which the gauge is mounted.

The primary source of error in resistance measurement originates from the wires and switches used to connect the resistor to the measurement device (see Figure 7-4). If the same wires are used to source the current and measure the voltage, an error results because of the additional, unknown resistance of the wires. The best way of avoiding this type of error is to use a four-wire or Kelvin connection (see Figure 7-5) between the resistance to be measured and the measurement device. When a four-wire connection is used, the current flows in one pair of wires, while the voltage is sensed in another. In this way, voltages generated by the resistance of the current-carrying wires are not added to the measured resistance. This is especially important when switches or relays are included in the measurement path. The contact resistance of even the best relay changes with time and causes errors unless a four-wire measurement technique is used.

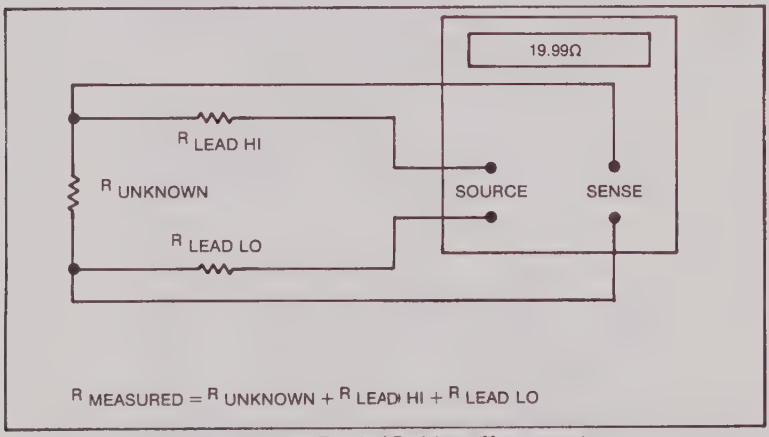


Figure 7-5. Four-Terminal Resistance Measurement

You must watch the power dissipated in the resistor being measured when you are doing resistance measurements. If the excitation current is too high, the temperature of the resistor may change. The value of most resistors changes with temperature. If the temperature change is too large, the measured value may be in error. This is called a self-heating error. Self-heating is a common source of error in measuring the small resistances of sensors like RTDs (resistance temperature detectors) and strain gauges. Most resistance measurement devices have specifications that include the amount of excitation current used for each resistance measurement range. Likewise, most resistance-type sensors specify the maximum allowable current to avoid self-heating problems. Be sure that the current used does not exceed the allowable levels.

Conductance

Conductance is the inverse of resistance. Conductance measurements are sometimes more useful than resistance when measuring such things as insulation leakage. The unit of conductance was formerly called the mho (ohm spelled backwards). The modern unit is the siemens.

Current

Current is a measure of the electron density passing through a conductor. The unit of measure for current is the ampere (amp). The most popular technique for measuring current is to cause the current to flow through a small, known resistance and then measure the resulting voltage across the resistor (see Figure 7-6). The resistor used in such a measurement is called a current shunt. The current is then found by Ohm's law (I=V/R).

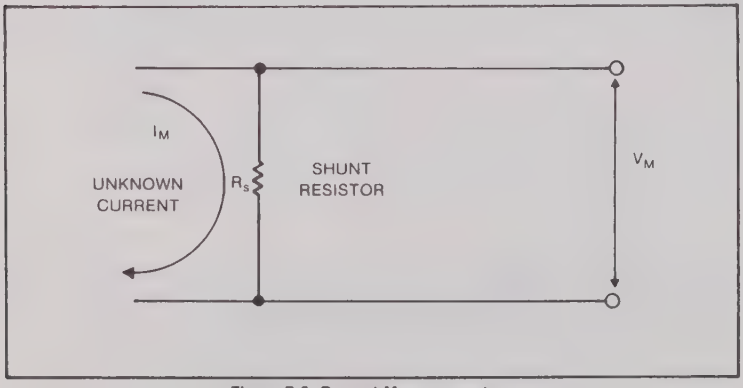


Figure 7-6. Current Measurement

For measuring alternating currents, another technique is to place a small coil of wire around the conductor carrying the current. Because of the transformer effect, an alternating current is induced in the pickup coil. This current is proportional to the current in the wire that runs through the pickup coil.

This technique is popular because it can be used for measuring the large alternating currents and voltages found in power distribution systems. However, the technique is generally less accurate than the shunt technique. It is also limited to alternating currents, while the shunt technique can be used for both alternating and direct currents.

One common source of error in making current measurements is compliance voltage problems. In the shunt technique, a small resistance is introduced into the circuit. If the introduction of this resistance loads the current source down so that the source voltage decreases, a reading error results. This problem usually occurs when a low resistance shunt is connected across a weak current source.

Frequency

The frequency of an ac signal is the number of times the amplitude of the signal completes one full cycle in a set period of time (usually one second). Frequency is measured in Hertz (Hz) (formerly cycles per second, cps). So, a signal of 10 MHz completes 10 million full cycles in one second.

Frequency measurement is done by counting the number of times the signal amplitude crosses a trigger level in a known gate time. The number of counts is divided by double the gate time (see Figure 7-7). For example, if 2,000 transitions of a signal were measured in 10 seconds, the frequency of the signal is 2,000/(2 x 10) = 100 Hz. The conversion from counts to frequency is usually done within the system-component instrument. The resulting value is presented in frequency units.

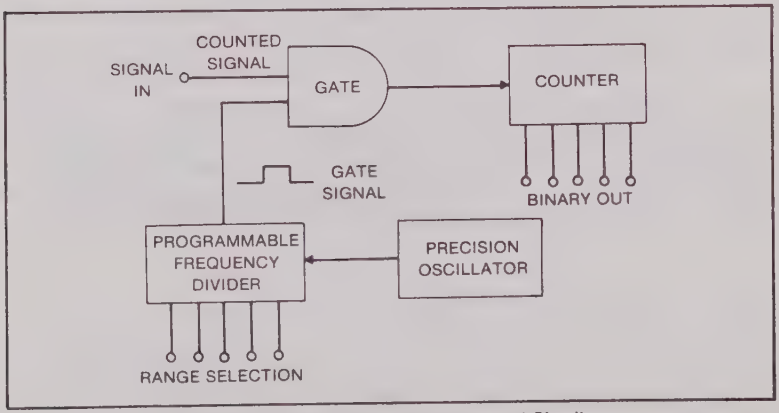


Figure 7-7. Basic Frequency Measurement Circuit

When measuring frequency, watch for noise, trigger level, and resolution. Noise may cause more or fewer transitions through the trigger level than should have been detected. The measurement may indicate a higher apparent frequency if the signal has a noise component with a higher frequency than the signal. Signal transitions may be missed if there is low frequency noise mixed with the signal.

Trigger levels must be set properly or no transitions of the signal will be detected and counted, or some transitions may be missed. This becomes especially important when measuring the frequency of signals with low amplitude. Many frequency measurement devices use auto-trigger circuits. These circuits sense the maximum excursion levels of the signal and adjust the trigger level accordingly. On other devices, the user must adjust the trigger level, either by commands over the system interface or through manual controls.

Resolution versus reading speed is always a factor in frequency measurement. The resolution available is a function of the frequency being measured and the time over which the count is done (gate time). If a short gate time is used, the resulting count is lower, and the resolution of the reading is reduced. Using a longer gate time to increase resolution decreases the reading rate. To avoid this, use a frequency measurement device that takes readings continually and buffers the readings in memory. This way, a recent reading is always available, even while a new reading is being counted.

In general, the lower the frequency, the longer the gate time needed to measure the signal to an acceptable resolution. One way to measure low-frequency signals is to do a period measurement and convert this to frequency. Many frequency counters allow this technique, which is described next.

Period

The period of an ac signal is the amount of time (in seconds) necessary for the amplitude of the signal to traverse one full cycle. Period is the inverse of frequency.

Period is usually measured by using the unknown signal as a gate signal to a signal of known frequency (see Figure 7-8). The transitions of the known signal are counted over a specific number of cycles of the unknown signal. The period of the unknown signal can be determined by the accumulated number of transitions of the known signal. Period techniques are sometimes used to measure the frequency of low frequency signals.

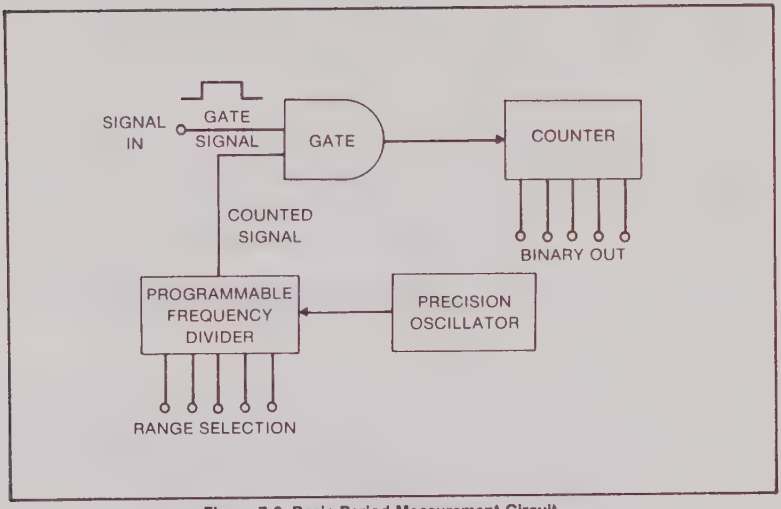


Figure 7-8. Basic Period Measurement Circuit

Power

The electrical power flowing through a wire is a function of the voltage, current, and the phase angle between the voltage and current (also called power factor). The usual unit of measure of power is the watt. One watt is one volt-amp, or one ampere of direct current flowing in a circuit under an electromotive force of one volt. In an ac circuit, power is defined as P = VI cos (phase angle), where V = volts, I = amps, and cos (phase angle) is the power factor. If the phase angle is zero, the ac power equation is the same as the dc equation.

Most power measurements are made to determine how much electrical energy is being used by a device, system, or facility. This measurement integrates the power used over time and has the unit of watt-hours.

Power measurements in electronic systems are a combination of voltage and current measurements, which were described previously.

Temperature

Temperature is the most measured parameter. It is the measure of the degree of heat or cold on a definite scale. There are three commonly used temperature measurement scales. The Celsius (or Centigrade) scale divides the temperature difference between the melting and boiling points of water into 100 increments, called degrees. The melting point of water is set to zero degrees and the boiling point of water is set to 100 degrees on the Celsius scale.

The Fahrenheit scale sets the melting point of water at 32 degrees and the boiling point at 212 degrees. Thus, on the Fahrenheit scale, there are 180 degrees between the melting and boiling points of water. The zero point of the Fahrenheit scale was derived using a mixture of sea water and ice, and (believe it or not) the 100 degree point was the armpit temperature of a healthy Englishman.

The Kelvin scale uses the same degree increment as the Celsius scale, but sets the zero point at absolute zero, or -273.15 degrees Celsius.

Temperature is always measured indirectly, by measuring the physical or electrical changes in a material because of a change in temperature. For example, various liquids expand and contract with a change in temperature. This is the basis for the mercury-in-glass thermometer.

Electronic measurement of temperature is done in one of three common ways: thermocouple measurements, resistance temperature detector (RTD) measurements, and semiconductor junction-related measurements.

THERMOCOUPLE TEMPERATURE MEASUREMENT

Thermocouples are two metal wires made of dissimilar materials and joined at two places called junctions. An electromotive force (emf) is generated when one thermocouple junction is at a different temperature than the other. This emf can be measured as a voltage. The U.S. National Bureau of Standards (NBS) has standardized the temperature versus voltage characteristics for several different combinations of thermocouple wire. These combinations are given letter designations by the American National Standards Institute (ANSI), i.e., Type J for iron versus constantan, Type K for chromel versus alumel, etc.

Refer to Figures 7-9 and 7-10 for diagrams of the two standard thermocouple measurement circuits.

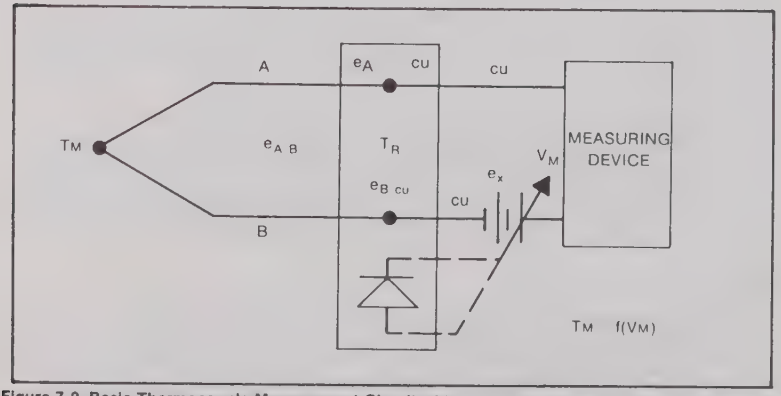


Figure 7-9. Basic Thermocouple Measurement Circuit with Analog Reference Junction Compensation

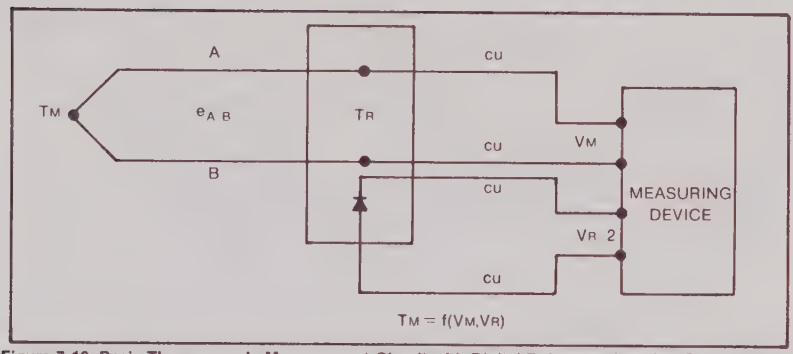


Figure 7-10. Basic Thermocouple Measurement Circuit with Digital Reference Junction Compensation

The voltage generated by a thermocouple is a function of the difference in temperature between the two junctions of the dissimilar wires (wires A and B in the circuit diagrams). The temperature of interest is only at the Tm junction in the diagrams. Therefore, the temperature at the other junction (Tr) must be held constant or measured. The Tr junction is called the reference junction because its temperature is known.

Thermocouple temperature measurement devices must be able to measure the voltage generated by the thermocouple and compensate this voltage for the temperature of the reference junction. Compensation is sometimes done by an analog circuit (Figure 7-9) that adds voltage to that generated by the thermocouple. In modern digital thermometers, the reference junction temperature is measured by a separate device, and the compensation is done mathematically (Figure 7-10).

Because of the need for reference junction temperature compensation, you can't just hook a thermocouple up to any voltmeter, measure the voltage, and convert the measurement to temperature. If you tried to measure temperature in this way, you would need to know the temperature of the terminals on the voltmeter. This is difficult to measure, and any error made in the reference junction compensation is reflected as an error in the actual temperature measurement.

Each thermocouple type follows a different relationship between the temperature at the junctions and the voltage generated. Electronic thermometers use various means of converting the voltage generated by the thermocouple to temperature. Recently, thermometers have used microprocessors to mathematically convert voltage to temperature.

Each thermocouple type has a recommended temperature range. Also, each type is can be used in differing environments. In the descriptions of thermocouple types on the next page, the color of the insulation on the positive lead is shown as the color code. The insulation on the negative lead of a thermocouple is always red.

THERMOCOUPLE TYPES

TYPE	MATERIALS	COLOR CODE	RECOMMENDED RANGE
J	Iron, constantan	White	0 to 760°C (32 to 128°F)

For use in vacuum, oxidizing, reducing, or inert atmospheres. Not recommended for sulfurous atmospheres above 500 C because of rusting and embrittlement. Type J should not be cycled above 760 C because of an irreversible magnetic transformation in the molecular structure.

K	Chromel, alumel	Yellow	-200 to +1260°C (-328 to +2300°F)

Used in oxidizing or inert atmospheres. Should not be used in vacuum at high temperatures. Corrosion problems in a low-temperature, oxygen atmosphere. Should not be used in sulfurous or reducing atmospheres.

T	Copper, constantan	Blue	-184 to 370°C (-300 to +698°F)

For use in vacuum, oxidizing, reducing and inert atmospheres. Not suitable for use in nuclear radiation because of composition changes. Care must be taken when using heavy gauge wires because of high heat conductivity along wires.

E	Chromel, constantan	Purple	-200 to +900°C (-328 to +1652°F)

For use in oxidizing or inert atmospheres. Should not be used in sulfurous or reducing atmospheres, or at high temperatures in a vacuum or low-oxygen atmosphere. Type E has the highest emf change per degree of any of the thermocouple types. Usually used in a protective tube or casing.

R & S	Platinum, platinum with rhodium (Type R: 13% Type S: 10%)		0 to +1450°C (32 to +2642°F)

Generally used for high temperature purposes. Should not be used in reducing atmospheres or any atmosphere with vapors such as lead, zinc, arsenic, phosphorus, or sulphur. Should be used in a non-metallic protective tube.

C	Tungsten with 5% rhenium, tungsten with 26% rhenium		0 to +2200°C (32 to +3992°F)

The type letter is not assigned by ANSI, but has become a de facto standard designation. Type C works best in reducing, inert, or vacuum atmospheres. It cannot be used in oxidizing atmospheres, air, or any atmospheres containing oxygen. It is usually used for very high temperature measurements.

THERMOCOUPLE JUNCTIONS, PROBES, AND WIRES

A thermocouple junction is formed whenever the two dissimilar metal wires of the thermocouple touch each other. Because of this, it is necessary to insulate the wires from each other at all places except where the temperature measurement is to be made.

Make a good junction between the wires at the measurement junction. Weld or solder the wires. Be careful to use a welding or soldering material that will withstand the maximum temperature expected and is compatible with the materials of the wires. Some wires, especially those made of tungsten, are exceedingly difficult to weld, so most manufacturers of thermocouple wires offer pre-welded probes and open wires.

The three most common junction types are exposed, ungrounded, and grounded (see Figure 7-11). An exposed junction is directly exposed to the material being measured. These junctions have fast response times, but they cannot be exposed to extreme environments, and are subject to mechanical damage.

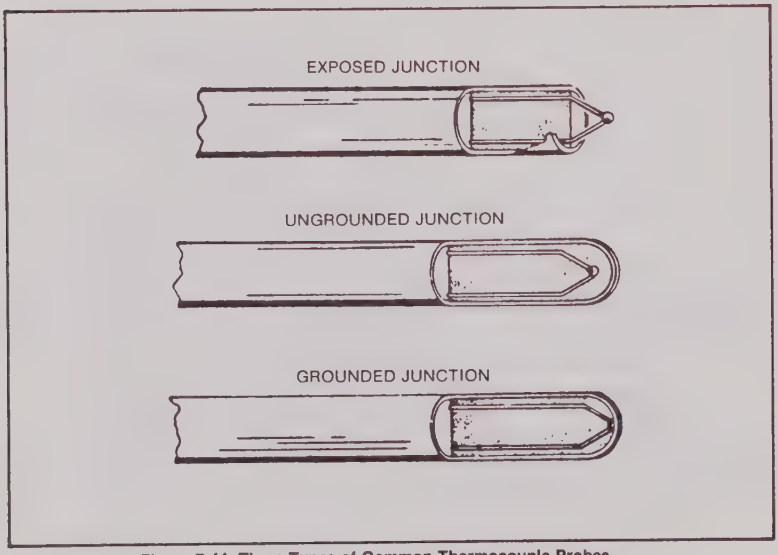


Figure 7-11. Three Types of Common Thermocouple Probes

Ungrounded junctions are completely enclosed in a sheath. They have slow response times, but they are both electrically and physically insulated from the environment. They are used in corrosive environments and where common-mode voltages are a problem.

Grounded junctions are completely enclosed in a sheath, but they are physically and electrically connected to the metal of the sheath. This connection decreases response time, but it allows the thermocouple to be electrically connected to the material being measured. Grounded junctions should not be used where high common-mode voltages are expected.

In exposed- or grounded-junction thermocouples, the wires are electrically connected to the spot where the temperature is to be measured. When this is done, you have to make sure that the voltage on that spot does not exceed the maximum common-mode voltage specification of your thermometer. For example, if the temperature of a 220-volt bus bar is to be measured with a welded-on thermocouple, make sure that the thermometer you are using can withstand 220 volts of common-mode voltage.

The normal-mode voltage specification of the thermometer becomes important in a failure condition. If one of the thermocouple wires breaks and contacts a ground point, all the common-mode voltage becomes normal-mode voltage. Most thermometers cannot withstand a normal-mode voltage above a few volts. Make sure that such a failure does not create a safety problem for operators.

If you are using a thermocouple probe assembly, you must use special wire to connect the probe to the thermometer. You must use either the same thermocouple wire as is used in the probe or special thermocouple extension wire matched to the wire used in the probe. If you use extension wire, make sure that the temperature where the thermocouple wire is attached to the extension wire is close to the temperature where the extension wire attaches to the thermometer. Too great a temperature difference between the ends of the extension wire will cause errors.

Thermocouple and extension wire is polarized, i.e., one wire is positive and one is negative. Make sure that the matching wires are connected to each other throughout the circuit. Also, make sure that the connection to the thermometer is correct. On insulated wires, the negative end is color-coded red, while the color of the positive wire shows the thermocouple or extension wire type.

THERMOCOUPLE MEASUREMENT ERROR SOURCES

Some common error sources are as follows:

1. Inadvertent junctions caused by the wires touching at unplanned spots.

2. Bad or loose connections between the wires and the thermometer.

3. Loose or corroded junctions at the measurement spot.

4. Reversed connection of the thermocouple wire to the thermometer, or to an extension wire. Contrary to most conventions, the RED wire is the negative one on thermocouple wires. The color of the positive lead indicates the thermocouple type.

5. Selection of the wrong wire type for the thermometer.

6. Use of too large a wire. This may cause heat to flow into or out of the area of the measurement junction, making the reading too low or too high.

RESISTANCE TEMPERATURE MEASUREMENT

In most materials, the resistance to current flow is a function of the temperature of the material. Resistance temperature detectors (RTDs) use this relationship to measure temperature. RTDs have been made of many different materials. Platinum is the most common RTD material, with copper, balco (an alloy material), tungsten, and nickel also being used. Copper RTDs are commonly found as a part of the winding in large motors and generators.

Temperature measurement with RTDs is simply a matter of measuring the resistance of the RTD and converting that resistance to temperature using mathematics or vendor-supplied tables. However, the relationship between resistance and temperature in RTDs is non-linear and complex. Modern RTD thermometers use microprocessors and mathematical techniques to do the conversion.

Standard Platinum RTDs (SPRTs) are used to define part of the temperature range of the International Practical Temperature Scale of 1968 (IPTS-68). However, SPRTs are laboratory devices and are too delicate for normal use. Industrial RTDs are somewhat less accurate than SPRTs, but they are much less expensive and more rugged. RTDs are popular where the accuracy and resolution needs are such that thermocouples cannot be used.

Industrial RTDs are identified by their **alpha constant.** Alpha is equal to the slope of the resistance vs temperature curve of the RDT, between 0 and 100 Celsius, divided by the resistance of the RTD at 0 Celsius.

alpha = (T100 - T0) /10000

For example, an RTD with a resistance of 100 ohms at 0 Celsius and 192 ohms at 100 Celsius, would have an alpha of

alpha = (192-100)/10000 = .0092 ohms/ohms/degree Celsius

The other primary RTD calibration constant is the resistance of the device at zero degrees Celsius. This constant is called R0. There are several other calibration constants for each RTD. These other constants are important if great accuracy is needed (better than .1 Celsius) or if very high or very low temperatures are to be measured.

The Deutsche Industrie Normen standards organization has developed a standard (DIN 43760) for RTDs with an alpha constant of .00385 ohms/ohm/degree C. Most RTDs have an alpha constant of between .00385 and .00392 ohms/ohm/degree C and an R0 of 100 ohms.

RTD MEASUREMENT ERROR SOURCES

Some common sources of error in RTD temperature measurement are:

1. Shock and vibration. These can cause the resistance of the RTD wire to change because of strains in the metal.

2. Improper immersion in liquids. The active region of most RTD probes is contained in the first 1 to 1 1/2 inches of the probe. The probe should be immersed at least four to six times depth of the active region to get the wire to the proper temperature.

3. Internal heating. Too much measurement current through the RTD can cause self-heating effects. The specifications for each probe includes a suggested excitation current level.

4. Exceeding the temperature range. Overheating can cause drift by driving impurities into the wire of the RTD.

5. Lead resistance. This is the most common source of error. Use a four-wire connection to the thermometer whenever it is practical. Use three-wire connections when you must, and use a two-wire connection only when the lead wires are short and high accuracy is not needed.

6. Using improper calibration constants. Most electronic thermometers have some way of adjusting for the various R0 and alpha constants of different RTDs.

SEMICONDUCTOR TEMPERATURE MEASUREMENT TECHNIQUES

Two techniques use semiconductors for temperature measurement. The first employs the thermistor, a device made of the compressed oxide of several different metals. The resistance of a thermistor decreases as its temperature increases. The relationship between the resistance of a thermistor and its temperature is non-linear and varies with the materials used, and with the manufacturer. To measure temperature using a thermistor merely requires measuring its changing resistance, and translating this value to a temperature.

Thermistors are popular because the resistance change that results from a specific change in temperature is large in comparison with other temperature sensors. This high thermal constant allows for high resolution readings. However, each type of thermistor can be used only over a narrow temperature range.

The other semiconductor technique uses the relationship between the base current of a transistor with constant emitter/collector current, and the temperature of the transistor. This relationship is linear. However, because of the physical construction of a transistor, this technique has a limited temperature range.

Strain

When a force is applied to a body, the body deforms. This deformation is called strain. The force per unit area on a given plane within a body is called stress. In general, the strain that can be measured within a body is a function of the stress the body in undergoing at the time.

There are four types of strain:

Tensile strain (see Figure 7-12) results from a stress that affects a lengthening deformation.

Compressive strain (see Figure 7-13) results from a stress that affects a shortening deformation.

Shearing strain (see Figure 7-14) is a measure of angular deformation.

Poisson strain (see Figure 7-15) is the thinning or fattening phenomenon that occurs as a secondary effect to tensile or compressive strain.

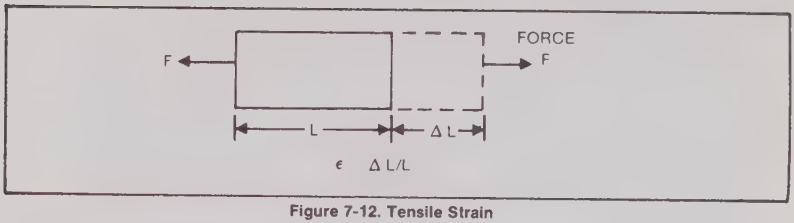


Figure 7-12. Tensile Strain

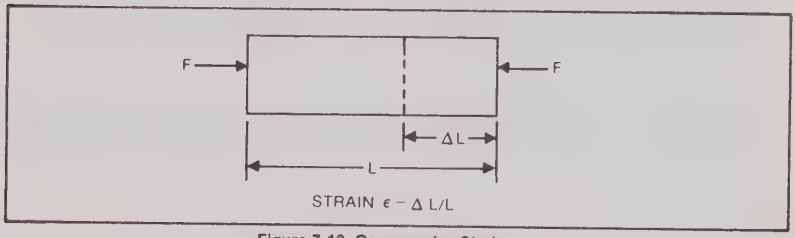


Figure 7-13. Compressive Strain

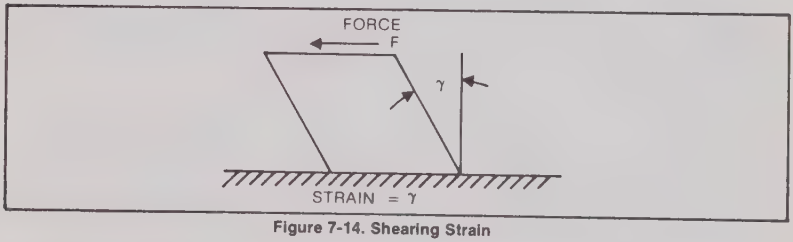


Figure 7-14. Shearing Strain

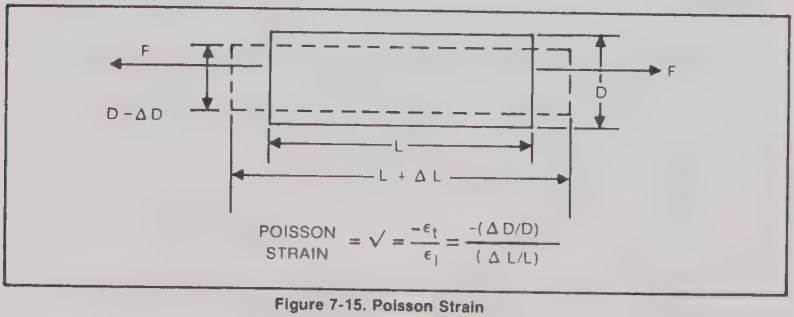


Figure 7-15. Poisson Strain

There are two types of stress: **normal** stress and **shear** stress. Normal stress (see Figure 7-16) is perpendicular to a plane, while shear stress (see Figure 7-17) is parallel to the plane.

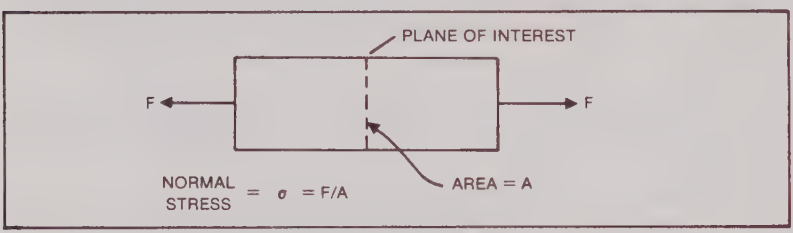


Figure 7-16. Normal Stress

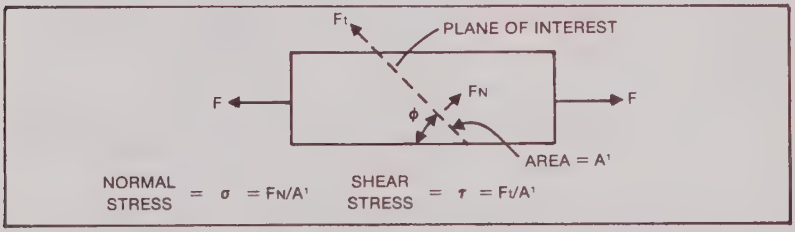


Figure 7-17. Shear Stress

The relationship between stress and strain is a function of the material. In many materials, this relationship follows Hooke's law (see Figure 7-18) up to a specific stress level. This level is called the proportional limit. Above the proportional limit, the stress-strain relationship is no longer linear.

STRESS = σ
STRAIN = ϵ
MODULUS OF ELASTICITY = E

HOOKE'S LAW

$$\sigma = E \cdot \epsilon$$

Figure 7-18. Hooke's Law

Since stress in a material cannot be measured directly, the strain is measured, and stress is computed from the measured value. In most conductors, the resistance to current flow varies with the relative deformation of the resistor. This phenomena is used to measure strain. There are many types of strain gauges available, but most of them are based on a resistor or set of resistors that vary in resistance with strain.

The ratio of the change in resistance of a strain gauge to the fractional change in length (strain) of the gauge is called the gauge factor. The gauge factor is the sensitivity of the gauge. The higher the gauge factor, the more sensitive the strain gauge.

Most strain gauges contain more than one resistor in a bridge configuration (see Figure 7-19). This is done to compensate the gauge for temperature changes and unwanted strain effects. Bridge configurations also increase the output of the strain gauge. Strain gauge bridges with two or more resistors require a constant voltage excitation and they output a voltage that is a function of the strain.

There are two basic strain measurement techniques: **static strain** and **dynamic strain.**

Static strain measurements are done with low reading-rate instruments (<1000 readings/sec). Static strain techniques are used to measure the stress on a structure under relatively constant loads.

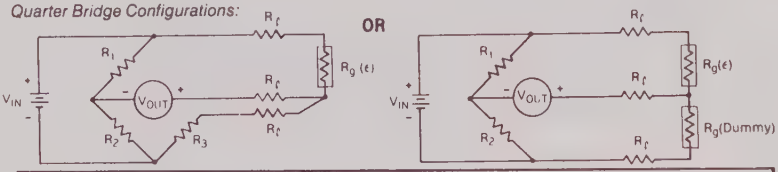
Dynamic strain, on the other hand, is measured by high-speed instruments and recording devices. Dynamic strain measurements are used in vibration analysis, destructive testing, and other high-speed testing applications.

Strain gauges are also used as sensing elements in such devices as scales and pressure transducers.

Equations compute strain from unbalanced bridge voltages:
sign is correct for V_{IN} and V_{OUT} as shown
GF = Gage Factor: ν = Poisson's ratio:

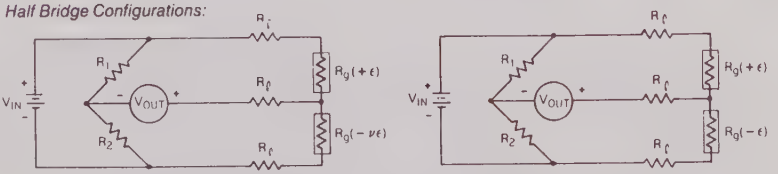
$V_r = [(V_{OUT}/V_{IN})\text{strained} - (V_{OUT}/V_{IN})\text{unstrained}]$:
ϵ = Strain; Multiply by 10^6 for micro-strain:
tensile is (+) and compressive is (−)

Quarter Bridge Configurations:



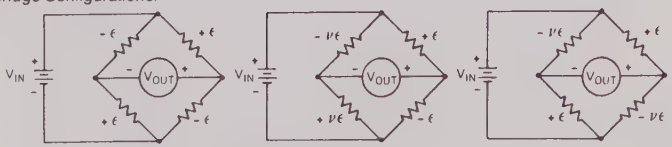
$$\epsilon = \frac{-4V_r}{GF(1+2V_r)} \cdot \left(1 + \frac{R_f}{R_g}\right)$$

Half Bridge Configurations:



$$\epsilon = \frac{-4V_r}{GF[(1+\nu)-2V_r(\nu-1)]} \cdot \left(1 + \frac{R_f}{R_g}\right) \qquad \epsilon = \frac{-2V_r}{GF} \cdot \left(1 + \frac{R_f}{R_g}\right)$$

Full Bridge Configurations:



$$\epsilon = \frac{-V_r}{GF} \qquad \epsilon = \frac{-2V_r}{GF(\nu+1)} \qquad \epsilon = \frac{-2V_r}{GF[(\nu+1)-V_r(\nu-1)]}$$

Figure 7-19. Strain Gauge Configurations

SIGNAL SOURCING

Although measurement is the primary function of test, measurement, and control systems, signal sourcing is also important, especially in test and control systems. There are four primary signal types sourced by these types of systems:

Voltage
Current
Resistance
Frequency

Most other signals sourced by test and control systems are variations on these four types. The techniques for producing these types of signals are discussed below.

Voltage

Over the years, there have been many different techniques developed for producing accurate dc voltages. The technique most used today in electronic test, measurement, and control systems, is digital to analog (D/A) conversion. D/A conversion is a good match to electronic systems because the value of the desired voltage is derived by a computer as a binary number. This binary number can be fed directly to the D/A converter to be converted to a voltage.

AC voltage sourcing is done using a source of ac voltage of a specific voltage and frequency (discussed below under frequency sourcing) and then passing that signal through a variable gain amplifier. The gain of the amplifier is usually controlled by a D/A converter of one of the types described below.

D/A conversion is done using one of two techniques: integration of a standard voltage or division of a standard voltage. In the integration technique (see Figure 7-20), a standard voltage is integrated for a variable length of time. The voltage is sampled and held at the end of the integration time. The time period is set according to the value of voltage desired. This technique is limited by the accuracy and stability of the standard voltage and the integrator circuit. However, the resolution of this technique is limited only by the time base used to generate the variable integration time.

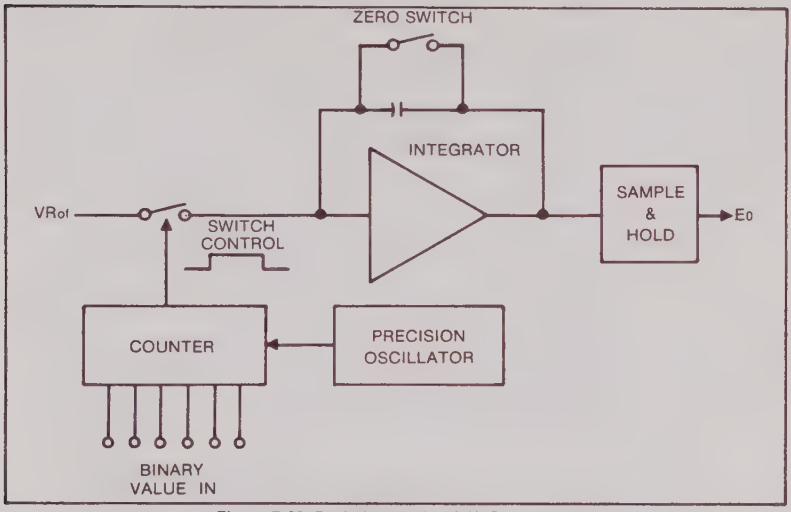


Figure 7-20. Basic Integrating D/A Converter

Divider type D/A converters use a network of precision resistors to divide a current or voltage from a standard voltage source (see Figure 7-21 and Figure 7-22. The current is summed and converted to a voltage by using an operational amplifier. The voltage is simply buffered by an amplifier. The resistors are switched into and out of the circuit using switches controlled by the binary value that is to be converted. This technique is limited by the precision and matching of the resistors used in the divider network. D/A converters of up to 20 bits have been produced using modern thin-film techniques and laser trimming.

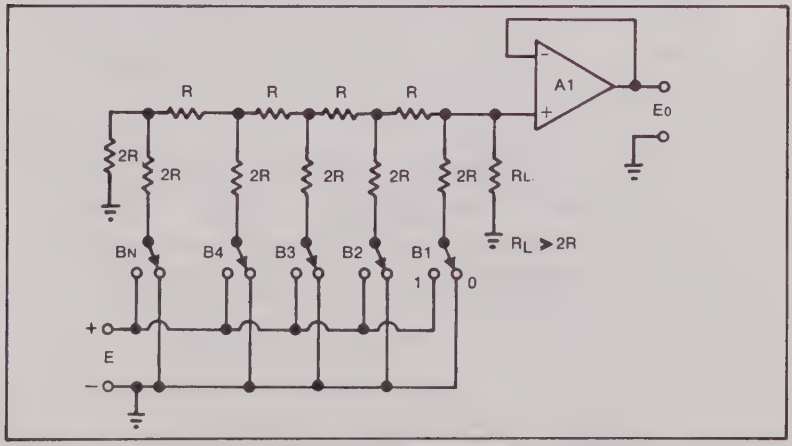


Figure 7-21. R2-R Resitor Ladder Network D/A Converter

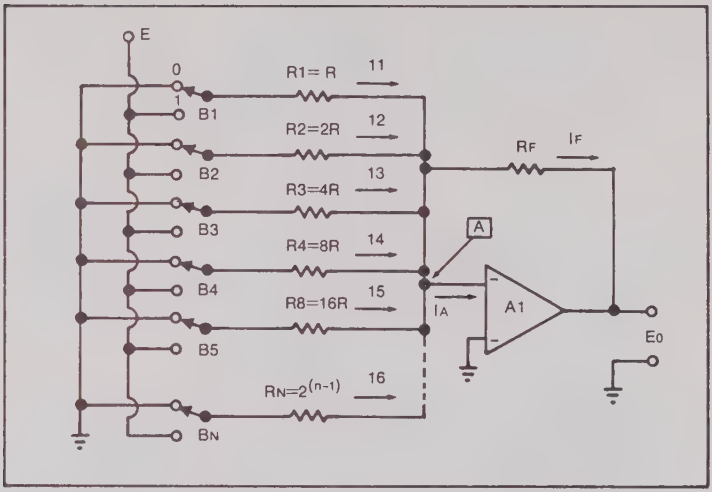


Figure 7-22. Binary Weighted Resistor Network D/A Converter

The following parameters must be reviewed when selecting a D/A converter:

Resolution The maximum number of bits of binary data that the converter is capable of converting to discrete output levels. For example, a 12-bit D/A converter has 4096 discrete output values of voltage.

Linearity The maximum deviation from a straight line output.

Offset The output of the D/A converter when the appropriate binary code for zero output is applied to the input. This value is usually a function of the temperature of the device.

Settling Time The time interval between a change in the binary input to the D/A converter and the achievement of a stable output that represents that input.

Stability The ability of the D/A converter to maintain a specific output once the settling time has elapsed. Stability mainly depends on the quality of the reference voltage source and temperature stability of the components used in the D/A conversion circuit.

Accuracy The ability of the D/A converter to generate output voltages that comply with the international voltage standard. This is mainly dependent on the reference voltage source used in the circuit.

Current

Precise variable currents in an electronic test, measurement, or control system are generated by a current-output D/A converter or a transconductance amplifier. Current-output D/A converters use the resistance network technique, but unlike voltage-output D/A converters, they don't convert the current from the resistor network into a voltage.

Transconductance amplifiers are devices that output a variable current that is a function of input voltage. A typical transconductance amplifier will have a transconductance of 1 ampere per volt. The input to a transconductance amplifier is usually a voltage-output D/A converter.

Resistance

Programmable resistance sources are less common than other forms of signal sourcing devices. Variable resistance sources are usually a set of fixed resistors combined with a set of switches. The device can be commanded to close and open the switches in a way that presents a selected resistance to the input terminals.

Programmable resistance sources are often used to program resistance-programmed power supplies. Other applications include meter calibration and transducer simulation.

Frequency

Before the advent of computer-controlled systems, variable frequency sources were controlled mechanically. The frequency of an oscillator was changed by varying the value of a capacitor or inductor, or by changing the shape of a tuning cavity. When computer control of the output frequency of a signal generator became important, various tuning techniques were tried, including motors to turn the old mechanical controls. Most modern signal generators use frequency synthesis techniques (see Figure 7-23). There are two common variations of frequency synthesis: **indirect synthesis**, and **direct synthesis**.

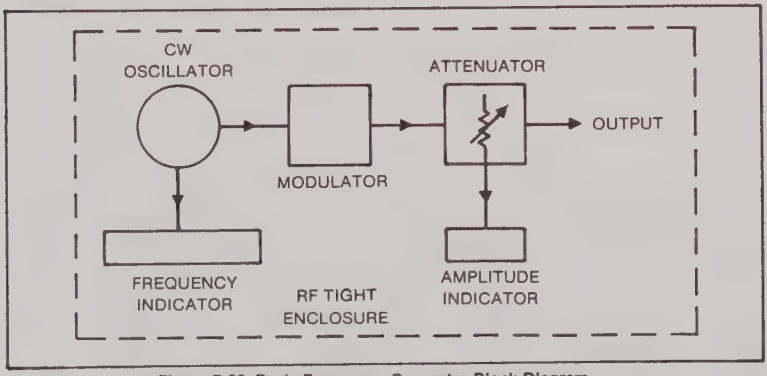


Figure 7-23. Basic Frequency Generator Block Diagram

The direct synthesis technique (see Figure 7-24) produces a reference frequency by a crystal-controlled oscillator fed into a harmonic generator. The output of the harmonic generator is a signal containing a wide range of frequencies. This signal is routed through a set of bandpass filters that filter out the specific frequencies required for output. The output from each of the bandpass filters is connected to an electronic switch matrix. Digital commands from the computer to the switch select the proper frequency signal for output.

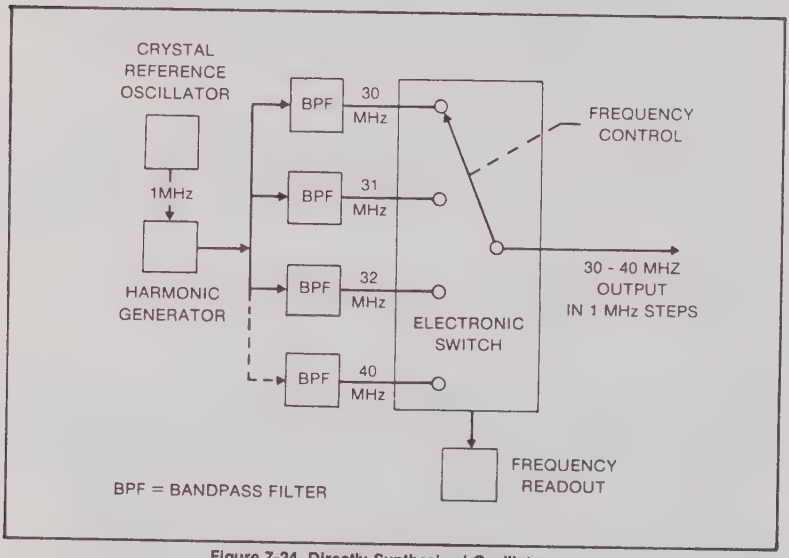


Figure 7-24. Directly Synthesized Oscillator

Indirect frequency synthesis (see Figure 7-25) is a technique in which signals of specific frequency are produced by an electronically-tuneable oscillator. This signal is divided down into a lower frequency signal by a programmable divider. The output of the divider is compared with a fixed frequency generated by a crystal-controlled oscillator. The comparison is done by a phase detector whose output controls the original tuneable oscillator. The frequency is varied by changing the value input to the programmable divider. This closed loop technique has good performance.

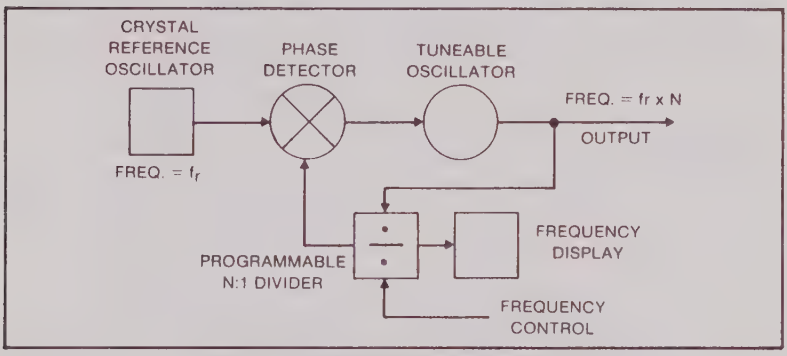


Figure 7-25. Indirectly Synthesized Oscillator

After the oscillator, the signals are further processed by wave shapers, modulators, dividers, doublers, mixers, etc, to produce the desired waveform and frequency (see Figure 7-23).

USER/OPERATOR INTERFACE

User and operator interfaces may be the most important component of any system. The operator of a system must be provided with just enough (but not too much) information. This information must be in a readable and unambiguous form. The operator's interface must aid in the process control of the system, not detract from it.

Video Display Terminals (VDTs)

The video display terminal or VDT is the most common operator's interface for computer-controlled systems. A VDT is a television-like device on which alphanumeric (letters, numbers, etc) and perhaps graphics (process diagrams, graphs, plots, etc) may be displayed.

Most VDTs have an attached typewriter-like keyboard for data entry. These keyboards may include a 10-key pad for number entry and various special-purpose keys.

VDTs are characterized by their capability to display different amounts and types of data. Several different types of VDTs exist, but the general classifications include:

1. Monochromatic-alphanumeric
2. Monochromatic-graphics, low to medium resolution
3. Monochromatic-graphics, high resolution
4. Color-graphics, low to medium resolution
5. Color-graphics, high resolution

The most common VDT has a monochromatic-alphanumeric display. This type of VDT uses two tones (black and white, green and black, amber and black, etc) and can display only alphanumeric characters (the alphabet, numbers, and some special characters). Most of these VDTs can display around 24 lines of characters, with each line being a maximum of 80 or 132 characters long. This type of VDT is used for general data capture, display and program development throughout the computer and systems industry.

The monochromatic-graphics low-to-medium resolution display adds the capability of displaying some graphics along with the alphanumeric information. In these terminals, each dot (pixel) on the screen can be controlled. In general, this type of VDT has a display resolution of up to 256 by 256 pixels. These VDTs are used to display simple line drawings, such as numeric line plots, pie charts, block diagrams, etc.

High-resolution monochromatic-graphics displays offer increased resolution over the low to medium resolution displays. Hihg-resolution displays start at 256 X 256 pixel resolution and go to over 4000 X 4000 pixel resolution. High-resolution VDTs are used to display process diagrams, drawings in computer aided design systems, mapping information, etc. This class of VDT is being replaced by color displays.

Color-graphics displays with low to medium resolution offer the same capability as the monochromatic display described above, but have the added ability to display more than two tones. Most VDTs in this class offer around 12 to 16 different colors. These VDTs are used in the same applications as stated above. The addition of color allows more information to be displayed in the same space than with a monochromatic display.

In the industry, high-resolution color-graphics displays are becoming the standard device for displaying process diagrams. This type of display allows a large amount of information to be displayed in a small space. A couple of these VTDs can give an operator access to as much information as an entire wall full of discrete displays and indicators.

Light Emitting Diode Displays (LEDs)

LEDs are made of an array of small semiconductor diodes that emit light when a electric current is passed through them. The arrays are arranged in a pattern such that numbers and letters can be shaped by turning on a particular set of the diodes.

LEDs are generally used to display numbers and annunciators on electronic instruments. Because of their high cost per character, lack of brightness, and high power consumption, LEDs are limited to a small number of characters. There are very few large, multi-line display systems that use LEDs. Because of the limited brightness of LEDs, they are difficult to read in direct sunlight. This limits their application to indoor applications where the light level is relatively low.

Liquid Crystal Displays (LCDs)

LCDs are constructed of a liquid material sandwiched between two sheets of glass or plastic. A pattern of conductive areas is plated onto the glass and the back sheet is a mirror. A charge placed on one of the conductive areas causes the nearby molecules of liquid to arrange themselves so that light is either blocked from reflecting from the mirror or allowed to pass through. The areas in which the light is blocked appear dark, while the other areas appear light. The conductive areas can be arranged so alphanumeric and even graphical information can be displayed.

LCDs are used in many applications for display of numbers, letters, simple graphics, etc. LCDs capable of displaying several lines of information have been developed. These large LCDs are being used in portable computers and other equipment.

The main limitations of LCDs are that they are slow, expensive (compared to VDTs), have a limited viewing angle, and require ambient light for viewing. However, they require little power. This makes them popular for use in portable, battery-operated equipment.

Vacuum Fluorescent Displays

Vacuum fluorescent displays operate much like a VDT except that they are thinner. A material making up each segment of the display gives off light when an electrical current is passed through it. The segments of the display are arranged so that characters, numbers, and other symbols can be formed by turning on and off particular sets of segments.

Vacuum fluorescent displays are becoming popular in the same type of applications in which LEDs have been used. They use less power than LEDs and are more efficient. However, they need higher voltages than LEDs, and this requires a more expensive power supply.

Analog Indicators

Analog indicators use the motion of a pointer or other such physical device to indicate the current value of a parameter. Examples of analog indicators include analog multimeters, chart recorders, bar graph indicators, clocks with hands, etc. These devices have been used for many years. They are not used much in computer-based systems because the analog value of the parameter is displayed directly, instead of being converted to a digital value first.

Analog indicators have limited maximum reading resolution (maximum of about 3-1/2 to 4-1/2 digits). They are, however, more useful than digital displays (such as VDTs, LEDs, and LCDs) when monitoring the change in a parameter or when making quick relative comparisons among readings. They are also more useful than digital displays when finding peak values of a parameter. Peaking is valuable when doing calibrations and adjustments. Because of this, many digital displays include a simulation of an analog display. This is done with simulated bar graphs and line plots.

DATA MANAGEMENT

Computer-based test, measurement, and control systems generate and manipulate large amounts of data. This data needs to be stored, displayed, printed in report form, and communicated to other systems. The data must be managed in a reliable, consistent manner. A Data Base Management System (DBMS) is an important tool for managing this data.

A data base consists of a collection of small records of data. The data base includes some way of quickly accessing these records based on some index or cross-reference scheme. The DBMS software associated with the data base maintains and access the data.

Data Base Management Systems were originally developed in the business data-processing industry, and were designed to handle the massive amounts of data generated by large business and government agencies. A DBMS consists of software packages to handle data storage and retrieval. There are two classes of DBMSs: **language-embedded** and the **independent** DBMS.

Language-dependent DBMSs are coupled with a programming language. The most common example of this type of DBMS is COBOL. COBOL is a popular business programming language because it includes powerful data base management statements and structures as an intrinsic part of the language.

Independent DBMSs are software packages that are independent from any particular language. They usually have an interface package that allows programs to access the data base. These packages also usually come with a built-in query language and report generation capability. Query languages are similar to programming languages, but are optimized for data base access.

There has been a trend to merge the language-dependent and independent DBMSs. This is because the managers of most large computer installations don't want to be dependent on a single language. Using an independent DBMS with good interfaces to several programming languages allows the system designer to select the best language for the task.

IEEE-488 BUS COMMUNICATIONS

In 1975, the Institute of Electrical and Electronic Engineers (IEEE) published an interface standard now amended and known as IEEE Standard Digital Interface for Programmable Instrumentation (IEEE Std 488-1978). The standard was revised in 1980, but the document retains the title IEEE Std 488-1978. The 1980 revision to the standard was done using revision pages. The current standard should be ordered using the title IEEE Std 488-1980 to get both the standard and the revision pages.

The IEEE-488 standard is accepted around the world. Many other official bodies have incorporated it into their own recommendations. This includes the International Electrotechnical Commission (IEC) recommendation 625-1 and the American National Standards Institute (ANSI) Standard MC 1.1.

Benefits of Using IEEE-488

Using the IEEE-488 standard, you can connect any two bus-compatible devices together and communicate without doing any mechanical, electrical, or low-level functional design.

Since the IEEE-488 standard has been in existence for several years now, there are thousands of compatible devices on the market. You can implement a wide variety of system functions using off-the-shelf IEEE-488 bus-compatible products.

There are many small- to medium-size computers that are specifically designed to do all the IEEE-488 Bus Controller functions. These "dedicated controllers" include interfaces and languages that are optimized for the development of system control software. Use of these controllers allows significant cost reductions in the systems and software design areas.

The connector and cable system illustrated in Figure 7-26 interconnects devices in an IEEE-488 bus-compatible system. These unique connectors allow excellent configuration flexibility because they can be stacked. The cable routing in a system can be changed without changing any software or switch settings. Devices can be quickly added or removed from a system. Cables are available in most countries of the world and require no changes to work in any standard IEEE-488 system.

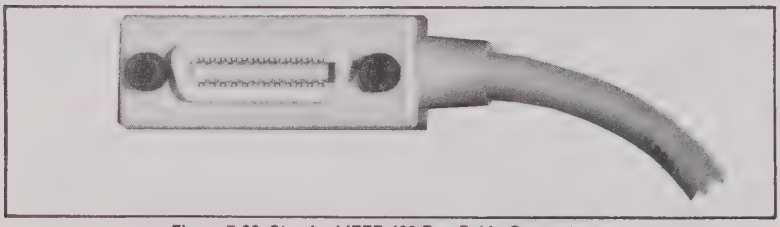


Figure 7-26. Standard IEEE-488 Bus Cable Connector

System maintenance is simplified in IEEE-488 systems because devices can be easily isolated and tested. Also, there are many IEEE-488 bus communication analyzers on the market. These analyzers can be used to find electrical, software, and functional problems in a bus system.

Each device on an IEEE-488 system is assigned one or more unique addresses. Even though the standard does not specify this directly, most manufacturers have chosen to place the bus address switches near the cable connector (see Figure 7-27). This allows quick access to the device addresses.

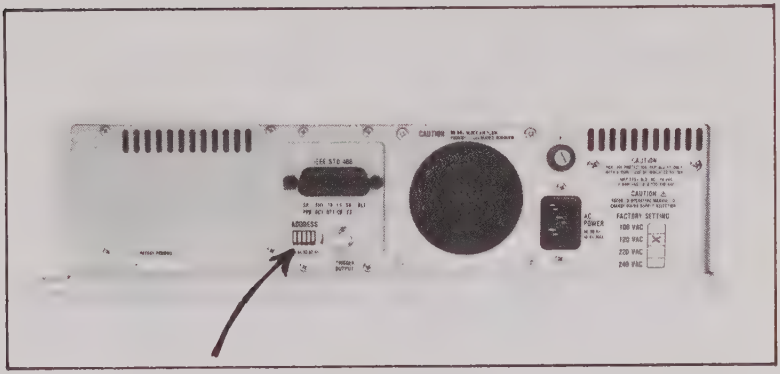


Figure 7-27. Address Switches

Only one controller interface is needed in any one IEEE-488 bus system. The Talker/Listener interfaces used by most instruments are simpler and less expensive than controller interfaces.

In summary, use of IEEE-488 allows the system designer to spend less time on detailed communication system design. It simplifies system implementation by its cable, address switch and connector design, and it simplifies system maintenance.

Like all communication systems, IEEE-488 has its limitations. These limitations of IEEE-488 must be considered when designing a system. These considerations are the next topic.

Considerations When Using IEEE-488 in Systems

The IEEE-488 standard defines a general-purpose communication system for use in limited-distance applications. In general, the following parameters must be considered:

1. Digital data is exchanged among the devices in an IEEE-488 bus system.

2. One contiguous bus can interconnect up to 15 devices (usually one controller and up to 14 instruments).

3. The total transmission path length over the interconnecting cables in an IEEE-488 bus system must not exceed the number of devices times two meters, or 20 meters total (whichever is less). However, many bus extension devices are available that allow almost unlimited distance between devices on a bus.

4. The data rate on any signal line across the interface in an IEEE-488 bus must not exceed 1 million bits per second (1 Mb/s). Most bus systems operate at a much lower data rate than 1 Mb/s.

5. Individual cable assemblies may be of any length up to 4 meters and must have a plug and receptacle connector at each end.

6. There can be only one active Controller at any one time on an IEEE-488 bus system.

7. There can be only one active Talker (but as many Listeners as necessary) at any one time on an IEEE-488 bus system.

Basics of Using the IEEE-488 Bus

To use the IEEE-488 bus does not require you to know much about the detailed workings of the bus. You purchase a controller and one or more instruments and other devices, and plug them together. However, you do need to be familiar with your application, software design and implementation techniques, as well as system configuration and integration techniques. The hardware and software in the controller and the other devices takes care of all the details of IEEE-488 bus communication.

The following sections are an introduction to some of the details of communicating on the bus. Be sure to read these sections if you want or need to:

-use a general-purpose computer rather than a dedicated controller

-use some of the less common bus functions

-fine tune the performance of an IEEE-488 system.

IEEE-488 Bus Control Computers

Dedicated instrument controllers have IEEE-488 bus control functions built in. However, if a general purpose computer is to be used as the bus controller, observe the following considerations.

To communicate with IEEE-488 bus-compatible devices, your host computer must satisfy the requirements for an IEEE-488 controller. Most desk top computers, minicomputers, and even some personal and mainframe computers have IEEE-488 bus controller interfaces and software available but you may have to buy software from some other vendor than the manufacturer.

The IEEE-488 interface is partitioned into subsets of interface functions, and not all applications use every subset. Your computer should support the IEEE-488 interface functions necessary for the devices selected for the system. For example, if a device requires SRQ, the controller must support the SR1 Interface Function subset.

If your computer is designed for IEEE-488 bus control, support for the interface functions are usually built into the programming languages. If the IEEE-488 features are not built into the language, they are usually implemented as standard subroutine or function calls.

In the lowest level of programming support, data is read from and written directly to the registers of the IEEE-488 bus interface circuitry (PEEK and POKE type interface). Programming is difficult when IEEE-488 communication is done with PEEK and POKE type statements.

Built-in IEEE-488 bus support is a definite advantage to the software developer. The difference in software development productivity between using a controller with built-in IEEE-488 bus I/O support and a slightly less expensive computer without this support is significant. This difference in productivity makes the purchase of a computer with better IEEE-488 support the more cost-effective alternative.

It is a complex task to design the hardware and write the software to implement IEEE-488 controller functions on a computer that lacks this capability. It is far less expensive to purchase a computer that has an interface available than to "do-it-yourself" on a machine that has no software or hardware available.

BASIC is the most popular language in IEEE-488 bus control computers, with HPL and FORTRAN the runners up. ATLAS is used extensively, mainly in large Automatic Test Equipment applications. Other languages, like Pascal, are gaining in popularity. Certain special purpose or single company languages like JOVIAL, APL and C have been adapted for use with the IEEE-488 bus. All these are higher level languages (HLL). Few people attempt IEEE-488 bus control using machine or assembly language.

Make sure that IEEE-488 bus input/output is supported by the higher level language (HLL) in the host computer. IEEE-488 bus I/O programming in machine language is unproductive. When purchasing an IEEE-488 controller interface from a third-party vendor, make sure that it includes software to allow IEEE-488 I/O from your chosen HLL. This software is usually called a driver or handler.

How The IEEE-488 Bus Operates

All the active IEEE-488 bus interface circuitry is contained in the devices attached to the bus. The connecting cable is passive (see Figure 7-26). The cable contains 16 signal lines, 7 ground returns, and a shield line. The cable connects all devices in parallel (see Figure 7-29). Some cables are wrapped with a shield, which is connected to the cable shield pin. Figure 7-28 below shows the connector with its signal assignments.

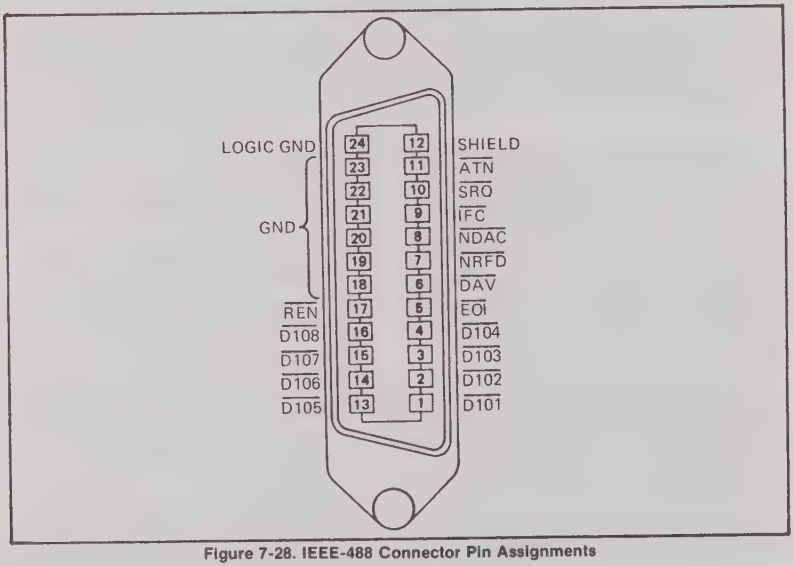


Figure 7-28. IEEE-488 Connector Pin Assignments

NOTE

Gnd. (n) refers to the signal ground return of the referenced contact. EOI and REN return on contact 24.

The signal lines of the cable are divided into eight data and eight control signals. Data and commands are transferred over the bus eight bits at a time in parallel on the data signal lines. Three of the control signals are used to handshake the data across the bus. The other five control lines are used to initialize the devices on the bus, begin or terminate messages, allow a device to get the attention of the Controller, and other such management tasks.

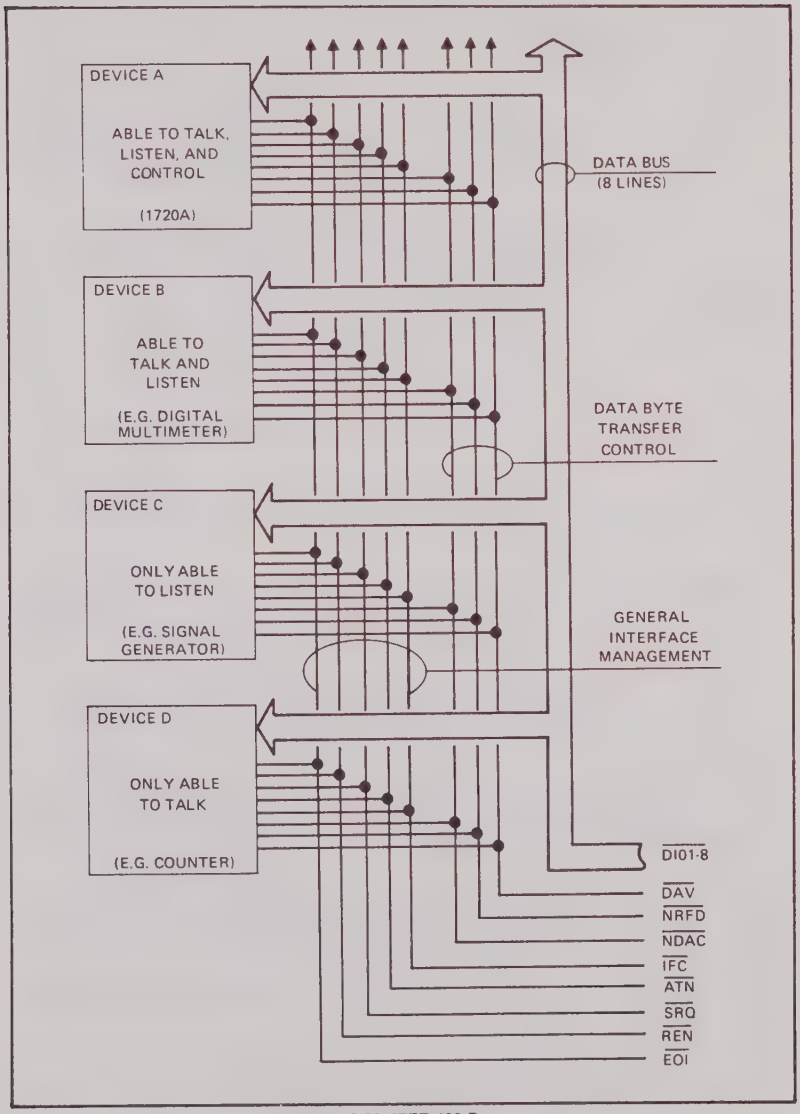


Figure 7-29. IEEE-488 Bus

The devices on an IEEE-488 bus system must be able to assume one or more of the following roles:

Talker — The device that is currently capable of putting data on the bus. A device (other than the Controller or a talk-only device) must be addressed as a Talker by the Controller to enter this mode. Once addressed as a Talker, the device will remain a Talker until its function is changed by the Controller.

A device referred to as an Extended Talker (TE function) is one that requires a secondary address to become an active Talker.

Listener — A device that is currently capable of accepting data from the bus. A device (other than the Controller or a listener-only device) must be addressed as a Listener by the controller to enter this function. Once addressed as a Listener, the device will remain a Listener until its function is changed by the Controller.

A device referred to as an Extended Listener (LE function) is one that requires a secondary address to become an active Listener.

Controller — A device capable of sending universal and addressed commands and of addressing devices. The Controller manages the operation of the bus system. It must be able to Talk and Listen, as well as Control.

A Controller has exclusive control of the ATN, IFC, and REN bus control signals (see the discussion below on bus control signals).

As mentioned before, there can be only one Talker on an IEEE-488 bus system at any one time. There can also be only one Controller. However, the current Controller may pass control to another device that is capable of becoming a Controller.

The simplest IEEE-488 system consists of one Talker and one Listener. Data transfer in this simple system is limited to direct communication between a device set to "talk only" and another device set to "listen only." An example of this is a data logger sending data to a printer.

Most IEEE-488 systems contain a Controller. In addition to handling data, the Controller is the system manager.

Bus Control Signals

Five IEEE-488 bus control lines are used to manage the interface:

Attention	(ATN)
Interface Clear	(IFC)
Remote Enable	(REN)
Service Request	(SRQ)
End Or Identify	(EOI)

The ATN line specifies how the data on the DIO lines are to be interpreted. If ATN is true, seven of the data lines are used to transmit addresses and universal commands. When ATN is false, the data lines are used to transmit device-dependent messages, such as data from a multimeter or setup commands to a switching device.

The IFC line places the bus interface in all devices into a known quiescent state.

The SRQ is most often used by a device to request attention. Most Controllers have a mechanism for changing the flow of control when a device sets SRQ.

REN (in conjunction with other messages) selects either remote or local control in a device.

EOI indicates the end of a multiple-byte transfer sequence. When a Controller sets both ATN and EOI true, each device capable of a parallel poll indicates its current status on the data line assigned to it. (For more on parallel poll, see Interface Functions later in this section).

Not every device must be capable of setting or responding to all the control lines. For example, many devices do not respond to a parallel poll. REN is typically not used on instruments with no local control capability.

Handshake Control Lines

The three handshake lines control transmission of data over the eight data lines. These three lines are:

Data Valid	(DAV)
Not Ready For Data	(NRFD)
Not Data Accepted	(NDAC)

Note that the true state of DAV is low while the true states of NRFD and NDAC are high.

A typical data transfer sequence is shown in Figure 7-30 on the next page. Immediately following the diagram is an explanation of the sequence. The steps in the transfer are described below the diagram. Follow the steps in the numbered bubbles in Figure 7-30.

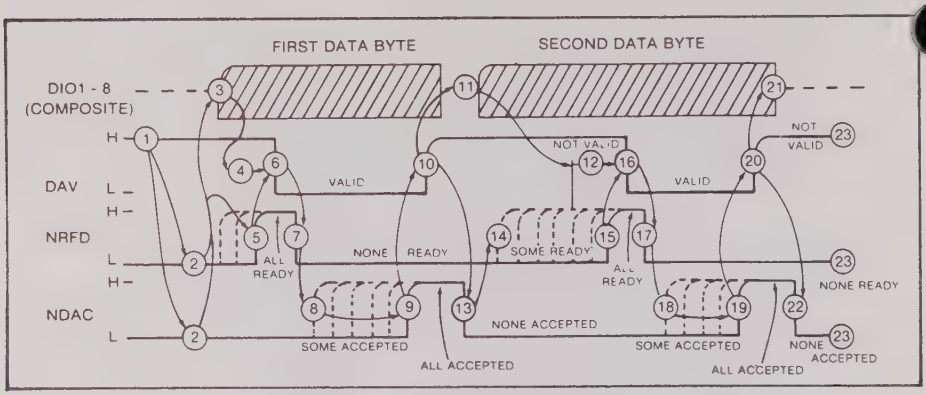


Figure 7-30. Data Handshake Sequence

1. The source (current Talker or the Controller with ATN true) initializes DAV false.

2. The acceptors (current Listeners or all devices when ATN is true) initialize NRFD and NDAC true (Note the negative logic.)

3. The source sets the data byte on the bus.

4. The source delays until the data settles and then waits for the acceptors to indicate that they are ready for data.

5. The acceptors release the active true condition on NRFD so that when all are ready, the line is passive false. This indicates to the source that all of the acceptors are ready.

6. The source sets DAV true to indicate that the data is valid.

7. An acceptor pulls NRFD to true, indicating that the acceptors are not ready for more data.

8. All the acceptors receive the valid data at their individual rates. As they do so, they let the NDAC line go from active true to passive false, so that when all have received the data, the NDAC line goes false.

9. The NDAC line goes false, indicating to the source that all acceptors have received the data.

10. The source sets DAV false.

11. though 22. The acceptors sense that DAV was set false and set NDAC true. This starts the cycle over for subsequent bytes.

The sequence just described occurs for any interface or device-dependent message byte transferred over the data lines.

As you can see from the description of the handshake sequence, data transfer happens at a rate established by the slowest of the devices accepting or sourcing the data. Because of this, the data transfer rate on the IEEE-488 bus is determined by the slowest of the devices on the bus. To get around this, some vendors of bus control computers offer two or more bus interfaces. Slow instruments can be placed on one bus and fast devices on another bus.

Device Addresses

Under normal bus conditions, all devices connected to the bus are passive until addressed by the system controller or a Universal Message. An address is a data byte transferred with the ATN line true. The lower five bits of the data contains the address. The seventh and sixth bits are:

01 to indicate that the device should become a Listener (MLA Message)

10 to indicate that the device should become a Talker (MTA Message)

11 to indicate a Secondary Address (MSA Message) See Figure 7-31.

The eighth bit is not used in addressing. Secondary addressing is done by sending a second data byte with bits six and seven both ones and the secondary address in the lower five bits.

The address of each device is assigned by one of the following techniques:

1. Set at the time of manufacture and not changeable.
2. Set by switches on the rear panel of the device.
3. Typed in from the front panel or keyboard of the device.
4. Set with jumpers on a printed circuit board inside the device.

While the ATN line is true, all devices must listen to the data lines. When the ATN line is false, only the devices that have been addressed may send or receive data. Several Listeners (but only one Talker) can be active simultaneously.

FLUKE®

ASCII & IEEE-488 BUS CODES

BITS B7 B6 B5 B4 / B3 B2 B1 B0	0 0 0 0 CONTROL	0 0 0 1 CONTROL	0 0 1 0 NUMBERS SYMBOLS	0 0 1 1 NUMBERS SYMBOLS	0 1 0 0 UPPER CASE	0 1 0 1 UPPER CASE	0 1 1 0 LOWER CASE	0 1 1 1 LOWER CASE
0 0 0 0	0 0 NUL NUL	16 10 ρ DLE	32 20 SP SPACE MLA0	48 30 0 0 MLA16	64 40 @ @ MTA0	80 50 P P MTA16	96 60 ` MSA0	112 70 p P MSA16
0 0 0 1	1 1 β SOH GTL	17 11 σ DC1	33 21 ! ! MLA1	49 31 1 1 MLA17	65 41 A A MTA1	81 51 Q Q MTA17	97 61 a a MSA1	113 71 q q MSA17
0 0 1 0	2 2 γ STX	18 12 τ DC2	34 22 " " MLA2	50 32 2 2 MLA18	66 42 B B MTA2	82 52 R R MTA18	98 62 b b MSA2	114 72 r r MSA18
0 0 1 1	3 3 δ ETX	19 13 υ DC3	35 23 # # MLA3	51 33 3 3 MLA19	67 43 C C MTA3	83 53 S S MTA19	99 63 c c MSA3	115 73 s s MSA19
0 1 0 0	4 4 ε EOT SDC	20 14 φ DC4	36 24 $ $ MLA4	52 34 4 4 MLA20	68 44 D D MTA4	84 54 T T MTA20	100 64 d d MSA4	116 74 t t MSA20
0 1 0 1	5 5 ζ ENQ PPC	21 15 χ NAK PPU	37 25 % % MLA5	53 35 5 5 MLA21	69 45 E E MTA5	85 55 U U MTA21	101 65 e e MSA5	117 75 u u MSA21
0 1 1 0	6 6 η ACK	22 16 ψ SYN	38 26 & & MLA6	54 36 6 6 MLA22	70 46 F F MTA6	86 56 V V MTA22	102 66 f f MSA6	118 76 v v MSA22
0 1 1 1	7 7 BEL BEL	23 17 ω ETB	39 27 ' ' MLA7	55 37 7 7 MLA23	71 47 G G MTA7	87 57 W W MTA23	103 67 g g MSA7	119 77 w w MSA23
1 0 0 0	8 8 BS BS GET	24 18 Ω CAN SPE	40 28 ((MLA8	56 38 8 8 MLA24	72 48 H H MTA8	88 58 X X MTA24	104 68 h h MSA8	120 78 x x MSA24
1 0 0 1	9 9 HT HT TCT	25 19 √‾ EM	41 29)) MLA9	57 39 9 9 MLA25	73 49 I I MTA9	89 59 Y Y MTA25	105 69 i i MSA9	121 79 y y MSA25
1 0 1 0	10 A LF LF	26 1A → SUB	42 2A * * MLA10	58 3A : : MLA26	74 4A J J MTA10	90 5A Z Z MTA26	106 6A j j MSA10	122 7A z z MSA26
1 0 1 1	11 B VT VT	27 1B ESC ESC	43 2B + + MLA11	59 3B ; ; MLA27	75 4B K K MTA11	91 5B [[MTA27	107 6B k k MSA11	123 7B { { MSA27
1 1 0 0	12 C FF FF	28 1C ↑ FS	44 2C , , MLA12	60 3C < < MLA28	76 4C L L MTA12	92 5C \ \ MTA28	108 6C l l MSA12	124 7C ¦ ¦ MSA28
1 1 0 1	13 D CR CR	29 1D ÷ GS	45 2D - - MLA13	61 3D = = MLA29	77 4D M M MTA13	93 5D]] MTA29	109 6D m m MSA13	125 7D } } MSA29
1 1 1 0	14 E S0 S0	30 2E Σ RS	46 2E . . MLA14	62 3E > > MLA30	78 4E N N MTA14	94 5E ∧ ∧ MTA30	110 6E n n MSA14	126 7E ~ ~ MSA30
1 1 1 1	15 F SI SI	31 1F ≈ US	47 2F / / MLA15	63 3F ? ? UNL	79 4F O O MTA15	95 5F — — UNT	111 6F o o MSA15	127 7F ■ RUBOUT
2^3 2^2 2^1 2^0	ADDRESSED UNIVERSAL COMMANDS COMMANDS		LISTEN ADDRESSES		TALK ADDRESSES		SECONDARY ADDRESSES OR COMMANDS	

KEY

decimal / ASCII: 38 & 26 / & MLA6 / hex

1722A DISPLAY

IEEE-488

Form No F738 1/84

Figure 7-31. ASCII and IEEE (GPIB) Code Chart

Messages

There are two types of messages communicated over the IEEE-488 bus. A message may be either an **Interface Message** or a **Device-Dependent** Message.

Interface messages perform some action directly within the interface. These actions may or may not affect the operation of the device. Each of the interface messages have a standard mnemonic. For example, MLA is an interface message that means "My Listener Address." This message indicates that the five lower bits of the data byte is the address of a device that the Controller wants to be set as a Listener. See Table 7-1 for a list of Interface messages.

Table 7-1. IEEE-488 Interface Messages

MNEMONIC	MESSAGE NAME	DIO LINES
DCL	Device Clear	Y0010100
GET	Group Execute Trigger	Y0001000
GTL	Go To Local	Y0000001
LLO	Local Lock Out	Y0010001
MLA	My Listen Address	Y01LLLLL
MTA	My Talk Address	Y10TTTTT
MSA	My Secondary Address	Y11SSSSS
PPC	Parallel Poll Configure	Y0000101
PPE	Parallel Poll Enable	Y110SPPP (see note 1)
PPD	Parallel Poll Disable	Y111DDDD (see note 2)
PPR	Parallel Poll Response	xxxxxxxx (see note 3)
PPU	Parallel Poll Unconfigure	Y0010101
SDC	Selected Device Clear	Y0000100
SPD	Serial Poll Disable	Y0011001
SPE	Serial Poll Enable	Y0011000
TCT	Take Control	Y0001001
UNL	Unlisten	Y0111111
UNT	Untalk	Y1011111

Y = Don't Care
L = Listen Address
T = Talk Address
S = Secondary Address

NOTES

1. S specifies the sense of the parallel poll response. P specifies the PPR message to be sent on a parallel poll.

2. D specifies don't care bits that will not be decoded by the receiving device.

3. x = assigned bit. The instruments respond with their assigned bit.

Device-dependent messages transfer information between the devices on the bus. Messages are composed of ASCII-coded characters. The content of these messages is not standardized by IEEE-488. A companion standard to IEEE-488 (IEEE-728, Code and Format Conventions for use with IEEE Standard 488-1979 Digital Interface for Programmable Instrumentation) standardizes some device-dependent messages. Not all IEEE-488 bus compatible devices follow IEEE-728, because it was drafted several years after IEEE-488.

The most important distinction between the interface and the device-dependent types of messages is the state of the ATN line. Interface messages are sent exclusively by a controller and are transmitted with the ATN signal in a true state. All devices connected to a bus system must listen to all interface messages. On the other hand, device-dependent messages are sent with ATN false. These messages may be programming data sent to an instrument to set up for a measurement, numerical data that results from a measurement, information to be printed on a printer, etc.

A typical programming sequence is shown in Table 7-2. The sequence starts when the Controller unlistens and untalks all devices and then sets up device 2 as a Listener using the MLA Interface Message. The Controller then drops the ATN line and sends a device-dependent message to the Listener. Next the Controller unlistens and untalks all devices and then readdresses device 2 as a Talker using the MTA Interface Message. As soon as the Controller again drops ATN, the Talker sends a device-dependent message. The Controller acts as a Listener to receive the message.

Table 7-2. Typical IEEE-488 Program Sequence

MESSAGE	DATA	TYPE	ATN	EXPLANATION
UNL	X0111111	I	1	Controller sends an unlisten interface command to all devices.
UNT	X1011111	I	1	Controller sends an untalk interface command to all devices.
MLA2	X0100010	I	1	Controller addresses the device at address 2 as a listener.
V	01010110	D	0	Controller sends data to the addressed listener.
R	01010010	D	0	
1	00110001	D	0	
F	01000110	D	0	
?	00111111	D	0	
UNL	X0111111	I	1	Controller unlistens all devices.
UNT	X1011111	I	1	Controller untalks all devices.
MTA2	X1000010	I	1	Controller addresses the device at address 2 as a talker.
+	00101011	D	0	Addressed talker sends data to the Controller.
1	00110001	D	0	
.	00101110	D	0	
0	00110000	D	0	
1	00110001	D	0	
8	00111000	D	0	
1	00110001	D	0	
5	00110101	D	0	
9	00111001	D	0	
E	01000101	D	0	
+	00101011	D	0	
0	00110000	D	0	
CR	00001101	D	0	
LF	00001010	D	0	

X = Don't Care
I = Interface Message
D = Device-Dependent Message

Interface Functions

Not all IEEE-488 bus-compatible devices implement all the capabilities defined in the standard. The standard allows for devices to implement a subset of the interface functions. Appendix C of the IEEE Standard 488-1978 describes the allowable interface function subsets. The standard recommends that the interface function capability codes for a device be placed below or near the interface connector on each device. If the codes are not near the connector, they are usually found in the IEEE-488 bus section of the manual for the device. The 11 interface functions are listed below.

1. Source Handshake (SH)
2. Acceptor Handshake (AH)
3. Talker (T)
4. Listener (L)
5. Service Request (SR)
6. Remote/Local (RL)
7. Parallel Poll (PP)
8. Device Clear (DC)
9. Device Trigger (DT)
10. Controller (C)
11. Electrical Interface (E)

Each interface function has several subsets. Each subset is assigned a code. The codes are the one or two letters for the function (SH, T, DC, C, etc), optionally followed by an address extension letter (TE, LE, etc), followed by a number (TE0, RL2, etc).

Each of these subsets defines certain capabilities. For example, the Talker function subset T2 means that the device can be a basic Talker, and can respond to a serial poll, but it cannot be a talk-only device, and is not unaddressed if a MLA interface message is received.

The interface functions listed above are described in the following sections.

DATA TRANSFER CONTROL (SH, AH, T, L, AND LE FUNCTIONS)

The four Data Transfer Control Interface Functions are concerned with the basic transfer of data across the bus. All bus messages (both interface messages and device-dependent messages) require the completion of a handshake to accomplish the data transfer.

Source Handshake

The Source Handshake function (SH) is required of all Talkers (T1 through T8 or TE1 through TE8). The SH function allows the device to handshake the data to the Controller and other listening devices.

Acceptor Handshake

The Acceptor Handshake function (AH) is required of all devices that listen (L1 through L4 or LE1 through LE4). The AH function is required of all Talkers.

Talker and Extended Talker

The Talker (T) or Extended Talker (TE) function is required of all devices that need to source data onto the bus. Devices with Talker functions can respond to primary addresses. Devices with extended Talker capability will respond to secondary addresses. Table 7-3 shows the capabilities of devices with the various Talker functions:

Table 7-3. IEEE-488 Talker Function Capabilities

FUNCTION	BASIC TALKER FUNCTION	SERIAL POLL	TALK ONLY MODE	UNADDRESS FOR MLA OR MSA
T0, TE0	N	N	N	N
T1, TE1	Y	Y	Y	N
T2, TE2	Y	Y	N	N
T3, TE3	Y	N	Y	N
T4, TE4	Y	N	N	N
T5, TE5	Y	Y	Y	Y
T6, TE6	Y	Y	N	Y
T7, TE7	Y	N	Y	Y
T8, TE8	Y	N	N	Y

The ability to support a talk-only mode is important in those systems that don't need a Controller. These include an intelligent instrument talking to peripherals like a printer or plotter. In these cases, one device is placed in talk-only mode and the other in listen-only mode.

Unaddress for MLA or MSA is a feature that simplifies programming. Devices with this capability automatically unaddress themselves as a Talker if they receive a command to listen.

The serial poll is the most common way to determine the status of a device on the IEEE-488 bus. Serial poll is often used to determine which device is requesting service via the SRQ line. Many devices that interface with the IEEE-488 bus include several information bits in the byte returned to the controller by the serial poll. These bits may indicate whether the device is busy or finished with the current command, whether it is in an error condition, and other types of status.

The serial poll is a sequence of interface messages (MTA, SPE, Transfer Byte, and SPD). As a result of this sequence, a status byte is transferred from a device to the controller.

IEEE Standard 728 suggests that the functions of bits in the status byte be as follows:

DIO8	Device Dependent Status
DIO7	1 - Requested Service 0 - Not Requested Service
DIO6	1 - Abnormal Operation 0 - Normal Operation
DIO5 - DIO1	Device Dependent Status

The state of DIO7 shows whether the device was requesting service (setting SRQ). The error state of the device is shown in DIO6. The use of DIO8 and DIO5 through DIO1 is dependent on the device.

A serial poll performed on a device requesting service via the SRQ line usually resets that service request. The usual sequence is:

1. The Controller commands a device to request service on a set of conditions. For example, a device may be commanded to generate SRQ on the completion of a set of measurements so that the Controller can read the data.
2. The device detects the proper condition and pulls SRQ true.
3. The Controller detects the SRQ and interrupts its normal sequence to process the request.
4. The Controller performs serial polls on all the bus devices until the device requesting service is found.
5. The Controller performs any processing necessary for the requesting device.
6. The Controller resumes the normal sequence of operations.

Listener and Extended Listener

The Listener (L) or Extended Listener (LE) functions are required of any device that needs to receive data from the bus. Devices with listener functions respond to primary addresses, while devices with extended listener functions respond to secondary addresses. Table 7-4 shows the capabilities of the various listener functions.

Table 7-4. IEEE-488 Listener Function Capabilities

FUNCTION	BASIC LISTENER	LISTEN ONLY MODE	UNADDRESS IF MTA OR MSA
L0, LE0	N	N	N
L1, LE1	Y	Y	N
L2, LE2	Y	N	N
L3, LE3	Y	Y	Y
L4, LE4	Y	N	Y

The listen-only mode is important for peripheral devices like printers, VDTs, tape recorders, disk drives, etc. This mode allows these devices to print, display, or record data from a device on the bus without a bus Controller.

The Unaddress if MTA or MSA feature is a convenience for programmers. If the device has been commanded to be a Listener and it receives a command to talk, it automatically unaddresses itself to listen if it has this capability.

SERVICE REQUEST (SR FUNCTION)

SR0 = No Capability
SR1 = Complete Capability

The Service Request function uses the SRQ line to provide a mechanism by which the devices on a bus can gain the attention of the Controller. Any device on the bus may pull SRQ true. More than one device may set SRQ at one time. Because of this, once the SRQ is detected by the Controller, it must determine which device (or devices) is requesting service. The Serial Poll and Parallel Poll are the two ways that the Controller can determine which device is requesting service.

Many Controllers allow a software interrupt to occur when SRQ is detected. This is an efficient way of handling service requests. When using Controller interrupts to handle SRQ, it is important that the Controller software be designed properly. For instance, if a device is set to generate an SRQ every 10 microseconds, it is possible that no work, other than interrupt processing, will be done in the Controller.

PARALLEL POLL (PP FUNCTION)

PP0 = No Capability
PP1 = Remote Configuration
PP2 = Local Configuration

The Parallel Poll is infrequently implemented in IEEE-488 devices because it does a similar function to the Serial Poll and is less useful. Also, the Parallel Poll is somewhat more difficult to implement than the Serial Poll, both for the Controller and for a Talker/Listener.

The purpose of the Parallel Poll is the same as the Serial Poll, that is, to respond to a Service Request. The Controller can use Parallel Poll to determine the status of the devices on the bus.

To use the Parallel Poll, each device on a bus system must have been assigned one of the eight data I/O lines. A device with PP1 capability can be assigned a line by the Controller. A device with PP2 capability is assigned a line by a switch or jumper on the the device.

When the Controller requests a Parallel Poll, each device places its status bit on its assigned data line. Each device responds to a Parallel Poll with only one bit of information, but a Parallel Poll can return status from up to eight devices at once. In contrast, the Serial Poll can collect status from only one device at a time, but collects eight status bits from each device.

REMOTE/LOCAL (RL FUNCTION)

RL0 = No Capability
RL1 = Complete Capability
RL2 = No Local Lockout

The Remote/Local function switches a device between control over the IEEE-488 bus and control from its own front panel. This function is not implemented in all IEEE-488 instruments. For example, instruments that have no local control functions rarely implement this capability. Other instruments implement a variation of this capability using device-dependent messages.

DEVICE CLEAR (DC FUNCTION)

DC0 = No Capability
DC1 = Complete Capability
DC2 = Omit Selective Device Clear

The Device Clear function performs reset operations in the devices on a bus system. Device Clear resets the device to a known state. However, there is disagreement over what functions are done in an device when the Controller commands a Device Clear. Consult the manual for each device on the bus to find out what specific actions it takes when a Device Clear is commanded.

There are two varieties of Device Clear: **Universal** and **Selective.** A device with DC1 capability can respond to both types, while one with DC2 capability can respond only to Universal Device Clear. Universal Device Clear commands all devices on the bus to go through the clearing actions. Selective Device Clear commands only those addressed devices. Most Controllers allow access to both Universal and Selective Device Clear through different commands.

Remember, there is no agreement on what action a device is to take when a Device Clear command is received. Some devices just clear the current state of the IEEE-488 bus interface, while some go through a complete power-on-reset cycle.

DEVICE TRIGGER (DT FUNCTION)

DT0 = No Capability
DT1 = Complete Capability

The DT function allows the Controller to synchronize a bus device. In a normal use for Device Trigger, the Controller gets an instrument set up to take a reading and then uses the DT function to initiate the reading at a certain time or on an event.

CONTROLLER (C Function)

The Controller is the most complex interface function, having 28 standard Controller subsets. Even the notation to describe a Controller is slightly different from other devices. Controller codes are the letter "C" followed by one or more numbers indicating the function subsets selected. For example, C1, C2, C3, C4, C6 describe a Controller that has System Controller, Send IFC and take Charge, Send REN, Respond to SRQ, Send Interface Messages, Receive Control, Pass Control to Self, and Parallel Poll capabilities, but has no Take Control Synchronously capability. Figure 7-32 shows all the Controller functions and their capabilities.

ELECTRICAL INTERFACE TYPE (E FUNCTION)

E1 = Open Collector Drivers
E2 = Tristate Drivers

The E function gives the type of driver electronics used in the device or controller. Tristate drivers can achieve higher data rates than open collector types. The interface bus can operate at a data transfer rate of up to 250,000 bytes per second using E1 type drivers. Rates of up to 500,000 bytes per second are possible using E2 type drivers.

	CAPABILITIES										
IDENTIFICATION*	SYSTEM CONTROLLER	SEND IFC AND TAKE CHARGE	SEND REN	RESPOND TO SRQ	SEND I F MESSAGES	RECEIVE CONTROL	PASS CONTROL	PASS CONTROL TO SELF	PARALLEL POLL	TAKE CONTROL SYNCHRONOUSLY
C0	N	N	N	N	N	N	N	N	N	N
C1	Y	-	-	-	-	-	-	-	-	-
C2	-	Y	-	-	-	-	-	-	-	-
C3	-	-	Y	-	-	-	-	-	-	-
C4	-	-	-	Y	-	-	-	-	-	-
C5	-	-	-	-	Y	Y	Y	Y	Y	Y
C6	-	-	-	-	Y	Y	Y	Y	Y	N
C7	-	-	-	-	Y	Y	Y	Y	N	Y
C8	-	-	-	-	Y	Y	Y	Y	N	N
C9	-	-	-	-	Y	Y	Y	N	Y	Y
C10	-	-	-	-	Y	Y	Y	N	Y	N
C11	-	-	-	-	Y	Y	Y	N	N	Y
C12	-	-	-	-	Y	Y	Y	N	N	N
C13	-	-	-	-	Y	Y	N	N	Y	Y
C14	-	-	-	-	Y	Y	N	N	Y	N
C15	-	-	-	-	Y	Y	N	N	N	Y
C16	-	-	-	-	Y	Y	N	N	N	N
C17	-	-	-	-	Y	N	Y	Y	Y	Y
C18	-	-	-	-	Y	N	Y	Y	Y	N
C19	-	-	-	-	Y	N	Y	Y	N	Y
C20	-	-	-	-	Y	N	Y	Y	N	N
C21	-	-	-	-	Y	N	Y	N	Y	Y
C22	-	-	-	-	Y	N	Y	N	Y	N
C23	-	-	-	-	Y	N	Y	N	N	Y
C24	-	-	-	-	Y	N	Y	N	N	N
C25	-	-	-	-	Y	N	N	N	Y	Y
C26	-	-	-	-	Y	N	N	N	Y	N
C27	-	-	-	-	Y	N	N	N	N	Y
C28	-	-	-	-	Y	N	N	N	N	N

Figure 7-32. IEEE-488 Controller Functions

RS-232-C COMMUNICATIONS

First established in 1969 and later revised, Electronic Industries Association (EIA) standard RS-232-C defines the electrical and mechanical characteristics of an "interface between data terminal equipment and data communication equipment employing serial binary data interchange." RS-232-C is the most widely accepted standard for digital data communication. Few pieces of computer-related equipment are supplied without an RS-232-C interface option.

RS-232-C was originally derived as a standard for interfacing modems (modulator/demodulator devices) with computers and terminals. It has since become important as a communications technique in direct wired systems.

Because RS-232-C is usually used with modems, be sure to read the modem portion of this guide along with these paragraphs. Several of the terms used here (such as baud and bps) are defined in the modem section.

Benefits Of Using RS-232-C

RS-232-C standardizes the electrical interface requirements of a bit-serial communications system. The advantages of using RS-232-C are mostly related to its wide use and low expense. Almost every general-purpose computer system has some type of an RS-232-C interface option. Cables and interfaces are relatively inexpensive. The RS-232-C interfaces in computers are well supported by the operating system software within the computer.

Many system devices use RS-232-C for low to medium speed (19,200 bps or less) applications. This is especially true for operator interface devices such as display terminals, plotters, and printers.

Most modems use RS-232-C for local communication. By using a modem with the telephone system, global communication can be established.

Considerations When Using RS-232-C

The RS-232-C standard defines the electrical requirements, but it does a poor job of defining the functions for many of the circuit lines named in the standard. The standard also says nothing about data transfer protocols. Because of this, several of the lines have been used for differing functions, and a multitude of protocols exist. This is especially true in direct wired systems. Equipment using RS-232-C can usually be cabled using standard cables. Non-standard cables must sometimes be used where signal lines have been used for special functions.

The user of RS-232-C must always investigate the necessary protocol before connecting two pieces of RS-232-C equipment. Just because the electrical characteristics of an RS-232-C interface matches, this does not necessarily mean that communication can take place.

EIA Industrial Electronics Bulletin No. 9 helps clarify the use of RS-232-C. This bulletin explains some of the common applications for RS-232-C and presents some suggested control circuit state diagrams.

RS-232-C supports limited distance communication. The standard recommends that RS-232-C cables be no longer than 50 feet. Cables longer than this may be used if the load capacitance of the cable plus the receiver is less than 2500 picofarads. Several manufacturers of RS-232-C cables have been able to produce cables of several hundred feet that meet this requirement. If you require longer cables, you may need to use a modem pair or line drivers. Modems are discussed later in this section. Line drivers are devices that increase the power of the normal RS-232-C drivers to allow higher cable capacitance and resistance.

RS-232-C communication is usually point-to-point. That is, only two system components can communicate with each other over one cable or modem pair. Because of this, large systems using RS-232-C can have higher cabling and interface costs than those using bus systems like IEEE-488.

How RS-232-C Works

The RS-232-C standard assigns functions to the circuit on each pin of a 25-pin connector. The de facto standard connector used is the subminiature D-type (DB-25). The connector is female (socket) on data communication equipment (modems, cables, etc) and male (plug) on data terminal equipment (terminals, computers, printers, etc). Signal voltage level and timing requirements are prescribed by the standard, but character code, bit rate (baud), and the use of parity bits in RS-232-C compatible devices can vary.

Computers and terminals are usually termed data terminal equipment (DTE), and any device or cable that connects two pieces of DTE is termed data communication equipment (DCE). Modems and other such communication equipment are usually DCE. Table 7-5 shows the signal assignments for the 25-pin connectors for DTE and DCE.

Table 7-5. RS-232-C DTE and DCE Signal Assignments

PIN	CIRCUIT	DESCRIPTION	SOURCE
1	AA	Protective Ground	-none-
2	BA	Transmitted Data	DTE
3	BB	Received Data	DCE
4	CA	Request To Send	DTE
5	CB	Clear To Send	DCE
6	CC	Data Set Ready	DCE
7	AB	Signal Ground (Common Return)	-none-
8	CF	Received Line Signal Detector	DCE
9	-	Reserved for Data Set Testing	-none-
10	-	Reserved for Data Set Testing	-none-
11	-	Unassigned	-none-
12	SCF	Secondary Received Line Signal Detector	DCE
13	SCB	Secondary Clear to Send	DCE
14	SBA	Secondary Transmitted Data	DTE
15	DB	Transmission Signal Element Timing	DCE
16	SBB	Secondary Received Data	DCE
17	DD	Receiver Signal Element Timing	DCE
18	-	Unassigned	-none-
19	SCA	Secondary Request to Send	DTE
20	CD	Data Terminal Ready	DTE
21	CG	Signal Quality Detector	DCE
22	CE	Ring Indicator	DCE
23	CH	Data Signal Rate Selector	DTE
23	CI	Data Signal Rate Selector	DCE
24	DA	Transmit Signal Element Timing	DTE
25	-	Unassigned	-none-

In RS-232-C, the signal is carried by a varying voltage level between the signal lines and the signal ground line (circuit AB - Pin 7). The space state of a signal (a binary 0) is indicated by a voltage level more positive than +3.0V on a signal line, and a mark state (binary 1) is more negative than -3.0V.

A message consists of a series of mark and space states on the primary or secondary transmitted data and received data lines. The other lines are used to control the interfaces and DCE in the circuit.

The transmitted data line from one DTE must be connected to the received data line in another DTE to make a complete circuit. This is done by the DCE, which may be simply a cable with the transmitted and received data lines crossed over. When there is a passive connection between two DTEs, the DCE is called a "Null Modem." See Figure 7-33 for the configuration of a simple Null Modem.

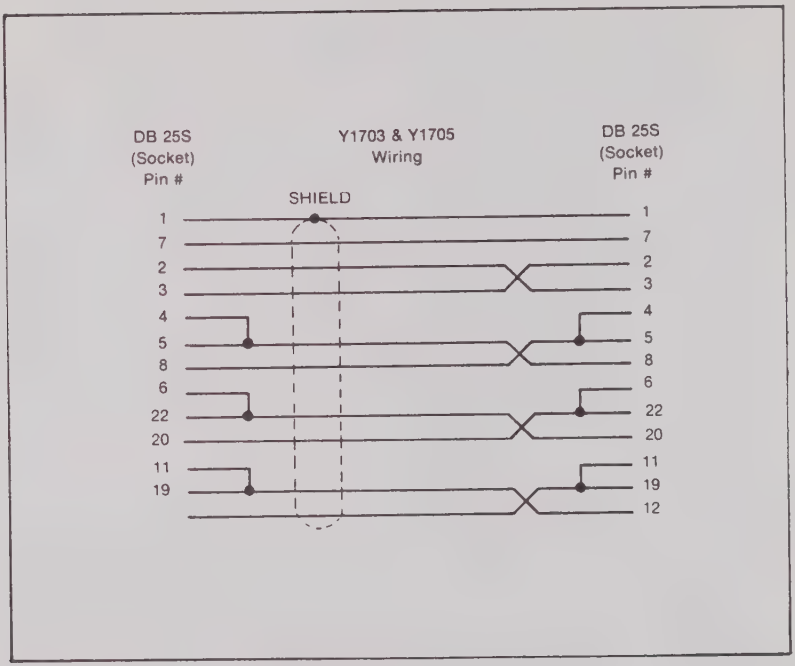


Figure 7-33. Simple Null Modem

One or more of the control lines are usually connected between the DTE and DCE in the circuit. All the signal control lines are rarely used in an RS-232-C circuit; many RS-232-C circuits consist of Transmitted Data, Received Data, Signal Ground, Protective Ground, and one or two control lines (usually Request to Send, Clear to Send, Data Set Ready, or Data Terminal Ready). The minimum RS-232-C set, consisting of the two data lines and one ground, is commonly used.

RS-232-C Signal Definitions

The names of each of the RS-232-C signals were shown in Table 7-5. The descriptions of each of these signals are given below.

Circuit AA — Protective Ground. This is usually tied to the chassis ground of the equipment or the power line ground.

Circuit AB — Signal Ground. This signal establishes the common ground-reference potential for all other signal lines (except Circuit AA).

Circuit BA — Transmitted Data. This is the primary data line originated by the DTE and received by the DCE. The DTE holds BA in a mark condition between transmissions. If they are implemented, Circuits CA, CB, CC, and CD must be in the mark condition for data to be transmitted on Circuit BA.

Circuit BB — Received Data. This is the primary data line received by the DTE and originated by the DCE. The DCE holds Circuit BB in the mark condition between transmissions.

Circuit CA — Request to Send. This signal is originated by the DTE. It prepares the DCE for data transmission by the DTE.

Circuit CB — Clear to Send. This signal is originated by the DCE. It signals to the DTE that the DCE is ready for data on Circuit BA.

Circuit CC — Data Set Ready. The signal on this line indicates the status of the local DCE. A mark condition on this line indicates that the DCE has established a communication channel and is not in a mode that inhibits communication.

Circuit CD — Data Terminal Ready. The signal on this line originated by the DTE to control the switching of the DCE to the communications channel.

Circuit CE — Ring Indicator. A mark condition on this line indicates that a ringing signal is being received on the communications channel.

Circuit CF — Received Line Signal Detector. A mark condition on this line means that a suitable signal is being received by the DCE over the communications channel.

Circuit CG — Signal Quality Detector. A mark condition on this line means that there is a low probability of an error on the received data.

Circuit CH — Data Signal Rate Selector (DTE Source). A mark condition on this line selects the higher data rate for the DTE in dual-transmission rate modems.

Circuit CI — Data Signal Rate Selector (DCE Source). A mark condition on this line selects the higher data rate for the DCE in dual-transmission rate modems.

Circuit DA — Transmit Signal Element Timing (DTE Source). Signals on this line provide timing information for transmitted signals from the DTE.

Circuit DB — Transmission Signal Element Timing (DCE Source). Signals on this line provide timing information for transmitted signals from the DCE.

Circuit DD — Receiver Signal Element Timing (DCE Source). Signals on this line provide the DTE with receive signal timing information.

Circuit SBA — Secondary Transmitted Data. This line is equivalent to circuit BA except that it transmits data via the secondary channel in reverse channel modems.

Circuit SBB — Secondary Received Data. This line is equivalent to circuit BB except that it receives data via the secondary channel in reverse channel modems.

Circuit SCA — Secondary Request to Send. This line is equivalent to circuit CA, except that it relates to the secondary channel.

Circuit SCB — Secondary Clear to Send. This line is equivalent to circuit CB, except that it relates to the secondary channel.

Circuit SCF — Secondary Received Line Signal Detector. This line is equivalent to circuit CF, except that it relates to the secondary channel.

Remember, some modem and computer equipment vendors use the circuits defined above for purposes other than those mentioned. Just because the product literature says RS-232-C compatible, does not mean that any two pieces of such equipment will communicate properly.

RS-449, RS-422, RS-423, AND RS-485 COMMUNICATIONS

Electronic Industries Association (EIA) Standard RS-449, first published in 1977, was intended to replace RS-232-C in most applications. However, RS-449 has not found general acceptance. The main differences between the specifications are the way that signals are carried on the wires. RS-232-C uses the difference in voltage between a wire and a common ground to carry the signal. An RS-449 interface uses a balanced (differential) voltage signal between a twisted pair of wires for most of the signal lines. This allows digital communication over as much as 4000 feet of twisted-pair 24-AWG wire at bit rates up to 90,000 bits per second (bps). Distances farther than 4000 feet can be supported at lower bit rates. RS-449 specifies a 37-pin connector for the primary circuit and a separate 9-pin connector for secondary circuits.

RS-422-A and RS-423 are separate documents that give the requirements for the cables, drivers, and receivers that are to be used in an RS-449 circuit. RS-422-A gives the specifications for the balanced differential signal lines. RS-423 gives the specifications for those lines in the RS-449 circuit that are unbalanced (common-ground) type signals.

RS-449 can sometimes be used without modems, since it supports higher speed and longer distance communication than RS-232-C. On the other hand, RS-449 is a much newer standard than RS-232-C. Far fewer devices and computers support RS-449 than RS-232-C. Noise is less a problem in RS-449 systems than in RS-232-C systems, because the high speed signals are carried by a balanced differential circuit.

RS-449 also supports multi-point, or party-line communication. More than two devices can be connected in parallel to one RS-449 cable run. However, using RS-422-A type drivers and receivers, there can be only one driving device on any one wire pair. The protocol to handle device addressing and control is not defined by the RS-449 standard and is implemented by each manufacturer or user.

RS-485 is an electrical extension to RS-422-A that allows more than one driver to exist on a wire pair. It allows up to 32 transceivers on a single line, but only one driver can be active at a time. Inactive drivers are tristated.

Several manufacturers have chosen to adopt the RS-422-A or RS-485 standards for balanced differential line drivers and receivers without using the RS-449 signal and connector assignments. This allows longer distance communication than RS-232-C, but it eliminates the need for the large 37-pin connector required for compliance with RS-449. Some details about the use of RS-422-A and RS-485 are given starting on the next page.

How RS-422 Works

RS-422-A specifies the electrical characteristics of a balanced voltage interface circuit for the interchange of serial binary signals between Data Terminal Equipment (DTE) and Data Circuit-Terminating Equipment (DCE). An RS-422-A circuit carries the signal as a difference in voltage between a pair of twisted wires. Contrast this to RS-232-C, where the signal is carried as a difference in voltage between one signal wire and a common ground return. RS-422-A offers longer distance and higher signaling rates than RS-232-C at the expense of having two wires for each circuit. An RS-422-A circuit is shown in Figure 7-34.

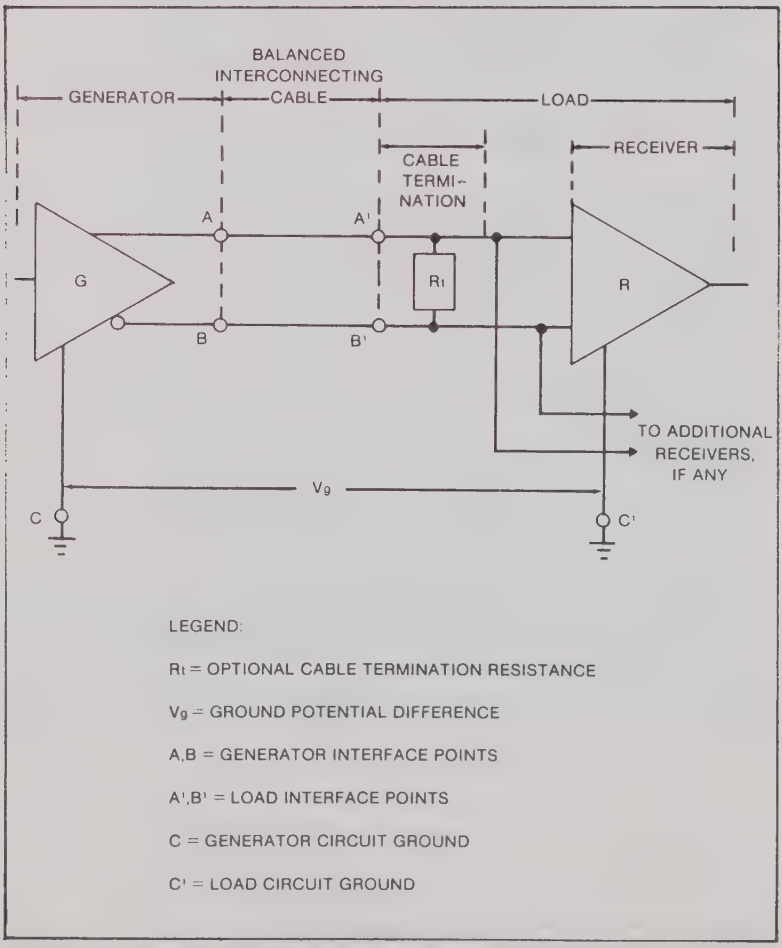


Figure 7-34. RS-422-A Circuit

RS-422-A specifies that there can be only one transmitter, but multiple receivers on a circuit. Because of this, it is useful only in simple, point-to-point communication circuits. Some manufacturers have extended their electronics beyond what the specification states to allow more than one transmitter on a circuit. RS-485 is a newer specification that standardizes this type of multi-transmitter circuit.

The RS-422-A specification does not define a protocol for controlling which of the receivers in a multiple-receiver circuit are to receive data. This protocol is defined by each vendor of RS-422 compatible equipment.

Recommendations on cable type and length are included in the RS-422-A standard. A plot of the recommended cable length versus the data signaling rate is shown in Figure 7-35. Using a 24 AWG, copper conductor, twisted-pair cable with a shunt capacitance of 16 pF per foot (telephone type cable), terminated in a 100-ohm resistive load, signaling rates up to 90,000 bps can be supported with a cable of up to 4000 feet. Higher signaling rates can be supported over shorter cables. Longer cables can support lower signaling rates.

The minimum RS-422-A cable consists of two wires for the signaling circuit. A reference to earth ground must be provided at each connection to the circuit. However, a two-wire connection supports only one-way communication. A four-wire cable can support two-way communication. Take care with the ground references at each piece of equipment to avoid ground loop currents. The cable should include a signal reference wire that is attached to ground at each piece of equipment attached to the cable.

Some applications of RS-422-A may require the use of a shielded cable. In these cases, the shield should be connected to the chassis of the equipment attached to the cable.

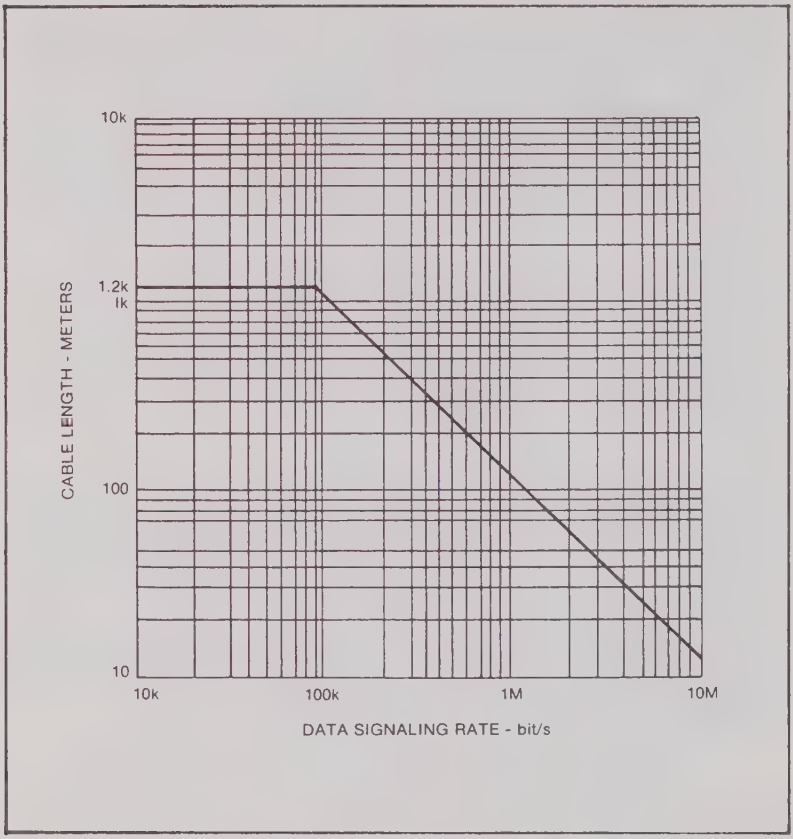


Figure 7-35. RS-422-A Signaling Rate vs. Cable Length

How RS-485 Works

RS-485 is an extension to RS-422-A that allows one transmitter on a wire pair to drive up to 32 unit loads. A unit load is a passive transmitter (transmitter in tristate mode), a receiver, or a transceiver (combination transmitter/receiver) the transmitter circuit is in the passive mode. RS-485 circuits allow party-line type communications. An RS-485 circuit is shown in Figure 7-36.

The RS-485 specification does not define the protocol needed to control which transmitter is active or which receivers are to receive data at any one time. This protocol is defined by each vendor of RS-485 compatible equipment.

Selecting a cable is somewhat more difficult for RS-485 than for RS-422-A. The curves shown in Figure 7-37 are used. Follow these steps:

1. Determine the minimum time between transmitted signal transitions. RS-485 refers to this time as the Unit Interval (**U.I.**).

2. Determine the minimum signal voltage that can be presented to the receiver. RS-485 refers to this voltage as **Vo**. The value of **Vo** must be equal to or larger than the worst allowable receiver margin. Receiver margins are usually published by equipment manufacturers.

3. Choose the maximum value of distortion allowable in the system. This information is usually only available from the equipment manufacturer.
4. Calculate the maximum allowable loop resistance using the formula:

$$Rloop = (Rterm\ (1.5-Vo)\ ) / Vo$$

Where:

Rloop is the maximum cable loop resistance in ohms.

Rterm is the cable terminating resistance in ohms, normally equal to the cable characteristic impedance.

Vo is the minimum signal voltage chosen above.

5. Choose a cable that provides a loop resistance equal to or less than **Rloop** over the required length.

6. Determine the 10% to 90% rise time of the signal for the cable selected in step 5. This is referred to as **tr**.

7. Calculate **tr/U.I.** from the values determined in steps 1 and 6. Use the curve in Figure 7-37 to find the selected value of **Vo** and the determined value of **tr/U.I.** Note the distortion shown. If it is less than the value chosen in step 3, the cable will provide satisfactory results. However, if the distortion value predicted by Figure 7-37 is higher than the necessary value, another cable should be chosen and the above calculations repeated.

The minimum RS-485 cable consists of two wires for the signaling circuit. A reference to earth ground must be provided at each connection to the circuit. This cable supports up to 32 transmitter/receiver pairs. Take care with the ground references at each piece of equipment to avoid ground loop currents. The cable should include a third signal reference wire that is attached to ground at each piece of equipment on the cable.

Some applications of RS-485 may require you to use a shielded cable. In these cases, the shield should be connected to the chassis of the equipment attached to the cable.

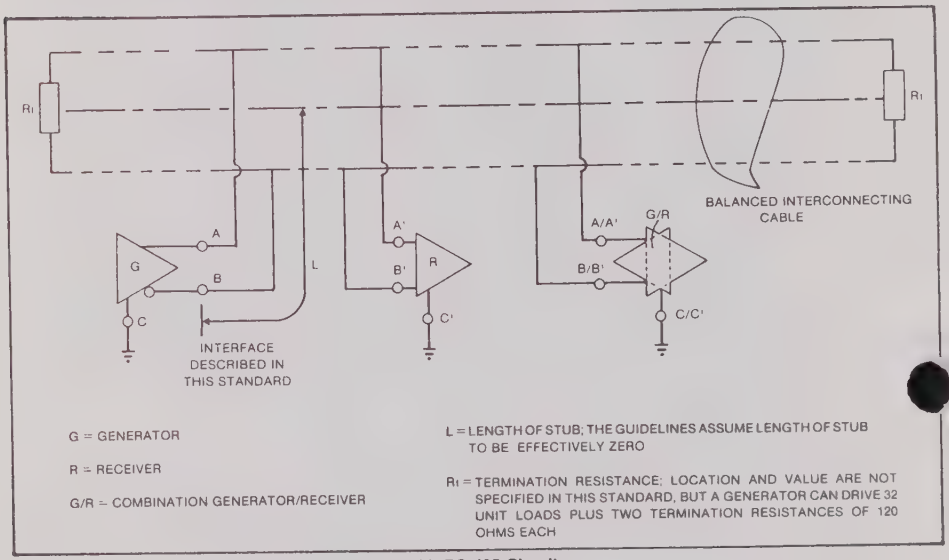


Figure 7-36. RS-485 Circuit

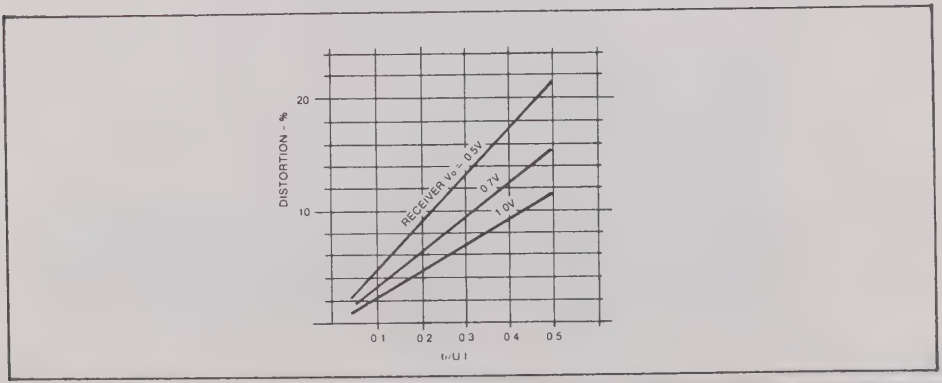


Figure 7-37. RS-485 Curve for Determining Distortion from Cable Rise Time (tr), Unit Interval (U.I.), and Signal Voltage Receiver

COMPUTER DATA NETWORKS

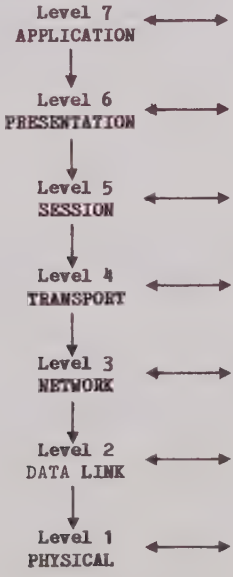
A computer data network is a collection of autonomous, but cooperating computers that share common transmission and switching media. A local area network (LAN) is a computer network that allows communication within a limited area, usually within one building or facility. A global data network is a computer network that covers a large area, usually only several miles but they can cover a truly global area.

Many different types of local area networks have been offered by vendors. Recently, the IEEE has made an effort to standardize both the physical portion of local area networks and the lower levels of protocol used to transfer data over such networks. However, because of the wide diversity of LANs in use, no specific limitations exist on the kinds of computer networks that can or cannot be called LANs.

Different industries have different terms for data networks. For example, in process control industries, data networks are usually called "data highways", while in the field of office automation, one vendor has referred to a data network as a "dialog link."

ISO Reference Model

In 1978, the International Standards Organization published the Basic Reference Model for Open System Interconnection, in an attempt to provide a consistent framework for network communication products. This publication, commonly known as the ISO Model, is structured as follows:



Each level has a specific set of assigned functions. A level may communicate with the level below it, above it, and with the equivalent level in another node in the network. More specifically:

Physical
This level defines the mechanical and electrical interface between the user and the network, including the connector, media type, signal levels, and signaling procedures for proper control of the connection. This level corresponds to RS-232-C or RS-449.

Data Link
This level controls the point-to-point exchange between two elements of the network or between the network and the user. This level implements the data link protocol. It corresponds to the interface functions in IEEE-488 and such protocols as IBM's SDLC (Synchronous Data Link Control) and and HDLC (High-Level Data Link Control) from the ISO.

Network
The network level provides a higher-level data path free from the dependencies on routing, connection request procedures, and so on. This level allows network users to share a level 2 link without interference. It also provides the means to request and clear calls, to notify a user of incoming calls, and control data flow so that network elements are not overloaded. The channel control techniques used in Ethernet and token-passing LANs are examples of this level.

Transport
This level is the user's gateway to the network. It calls on level 3 to establish the required network route. Its purpose is to establish a reliable path to support user communication. SNA (System Network Architecture) from IBM contains an implementation of level 4.

Session
This level uses level 4 to establish sessions of network communication. There are no accepted implementations of level 4 in any of the popular commercial networks.

Presentation
This level provides a means for parties on the network to communicate in spite of differences in data format. An early attempt at this level was the "virtual terminal" capability of the ARPANET, a very successful networking project of the U.S. Government's Advanced Research Projects Agency.

Application
The application level is the user interface to the communication facility. This level is tied to the operating environment and application programs running in each node in the network.

Levels 1 through 3 are implemented in many global and local area networks. The physical implementation and topology of the network correspond to level 1. The protocol used to transfer data over the network corresponds to level 2, and the network channel control corresponds to level 3. Above level 3, things are not so simple. Many networks don't specify anything above level 3, allowing each individual implementor to choose his own techniques. Other networks combine the functions of several levels into one level or leave out functions.

The three common attributes by which local area networks are classified are: **Topology, Channel Control Technique,** and **Physical Implementation.** Since the LAN is the network type that is most often used with test, measurement, and control systems, these topics are discussed in detail in the following sections.

Network Topologies

The term "Network Topology" refers to the geometric arrangement of the links and nodes that make up the network. This is included in level 1 of the ISO model described above. A node is usually a computer, terminal, or other such device that receives or sends data, while a link (also called a line, channel, or circuit) is the communications path between two nodes.

Most LANs are based on either a star, ring, or bus topology. See Figures 7-38, 7-39, and 7-40). In a star network, there is a central node with links radiating out from it. Each radial link terminates in an outlying node. Star networks require central control. The main problem with the star arrangement is that if the central node goes down, the whole network goes with it. However, star networks have simple control structures and do not require outlying nodes to have much intelligence. Star networks are used extensively in timesharing applications. The central node serves as the timesharing host, and the outlying nodes are dumb terminals.

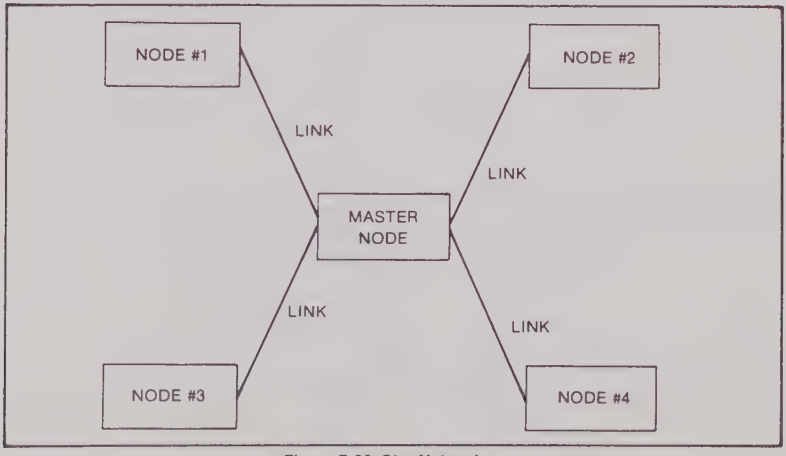


Figure 7-38. Star Network

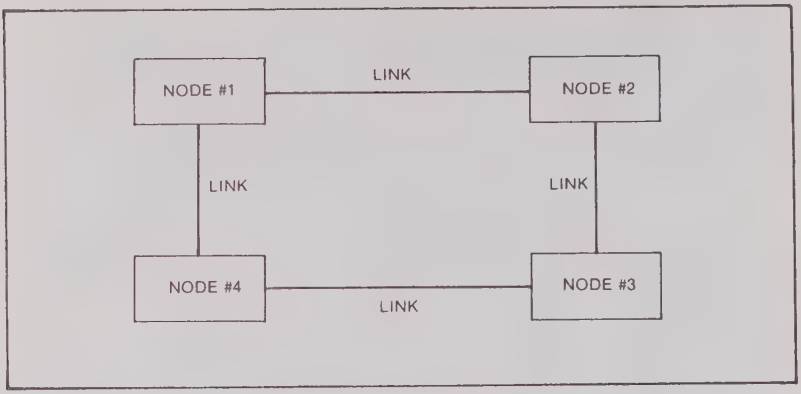


Figure 7-39. Ring Network

In a ring network, each node is attached to only two other nodes. Transmitted messages travel from node to node around the ring. Each node receives each message, recognizes those that are addressed to it, and repeats only those messages not addressed to it. One problem with this approach is that the failure of one node in the ring may cause the whole ring to fail. Wiring a building with a ring is difficult because the main network cable must pass through each node. However, rings tend to have less complex control than other schemes, because message routes are determined by the topology.

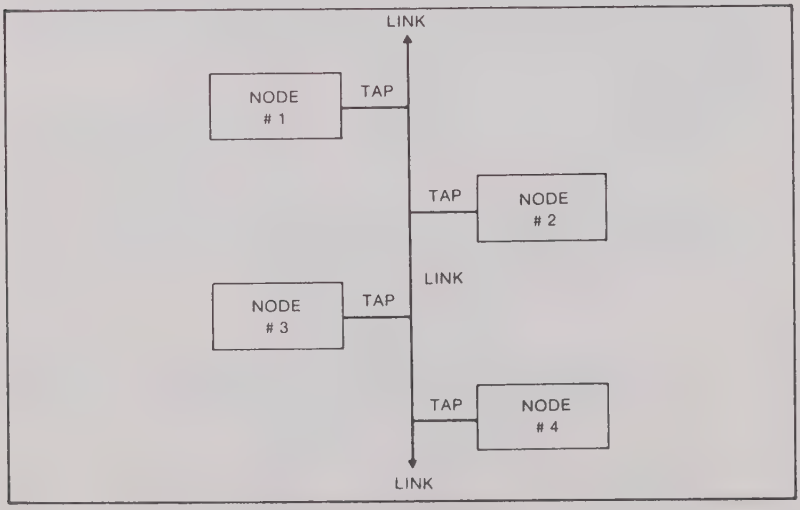


Figure 7-40. Bus Network

Bus networks are characterized by a single link with cable taps that run off to each node. In effect, each node on a bus is attached directly to every other node in the network. Each node in the network must receive each transmission and recognize its own addresses. Bus systems are easy to install and maintain. A new node is placed on a bus simply by tapping the bus cable. Some mechanical systems are available to do this while the network is live without affecting operation. Failure of a node in a bus system rarely causes the entire bus to fail. However, control of a bus system is more complex than in either the star or ring topologies.

Network Channel Control

There are three common approaches to channel control in local area networking:

Polling
Token-passing
Contention

Channel control corresponds to level 3 in the ISO model.

In the polling approach, a network controller polls each device to see if it wants to communicate. When a device wants to transmit, it has to wait to be polled by the controller and then gets control of the network for an interval or message size determined by the controller.

In the token-passing approach, each device (in turn and in a predetermined order) receives and passes the right to use the network. The right to use the network is called "the token." If a computer on the network wishes to transmit a message, it must wait until the token is passed to it, and then "hold" the token while it sends its message. When a computer is finished transmitting, it must pass the token on to the next computer in the network.

The contention approach is also called "Carrier Sense-Multiple Access with Collision Detection CSMA/CD." In this style of networking, when a computer wishes to transmit information over the network, it only does so when there are no other transmissions on the network. This may lead to a "collision" because of simultaneous transmissions. These collisions are detected and each transmitter abandons its transmission, waits for a brief interval and tries again. This approach is used in the Xerox EtherNetwork.

Both a token-passing (IEEE-802.4) and a CSMA/CD (IEEE-802.3) technique have been standardized by the IEEE P802 project. This same project is working on broadband and other LAN techniques. This standardization effort should add to the popularity of local area networking techniques.

Network Physical Implementation

The next few pages describe the three most popular physical implementation techniques for Local Area Networks.

Private Branch Exchange (PBX)
A PBX is a local telephone switching system. These systems have been expanded to include a mixture of analog voice and digital data signals, and are usually arranged in a star topology. PBX systems use a twisted-pair wire medium, which limits the data speeds to a maximum of 56,000 bits/second. PBXs are used for in-house timesharing communication between central computers and remote terminals. They are also used for low speed computer-to-computer communication of electronic mail, management information, messages, and so forth, making them popular in personal computer networks. Installation costs are low for PBX systems because they use existing telephone wire systems.

Broadband LAN
This type of network uses frequency-division multiplexing techniques to carry several information channels on one coaxial cable. This technique was developed for cable TV systems. Digital signals carried on a broadband system are modulated onto an analog carrier signal. Broadband systems can carry a mixture of analog signals (like TV for video-conferencing) and modulated digital signals on a single cable. Each channel on a broadband LAN is assigned a portion of the 300- to 400-MHz bandwidth available on the cable. Broadband LANs are usually found in either ring or bus topologies.

Baseband LAN
In this networking technique, the digital signal is carried in its original form on the cable. Baseband signals are not modulated onto a carrier signal, so only a small portion of the available bandwidth of a coaxial cable is used and expensive modulation/demodulation equipment is avoided. Baseband LANs can carry only digital data. Both twisted-pair wire and coaxial cable are used in these systems. Baseband LANs normally use a bus topology. The most popular baseband LAN is the Ethernet (CSMA/CD contention technique), developed by the Xerox Corporation.

TELEPHONE AND OTHER CARRIER SYSTEMS

The most popular communications media are direct-wire and voice-grade circuits on the public telephone systems. As data communication media, voice-grade telephone circuits have several advantages and disadvantages. These are discussed below.

To use a voice grade telephone circuit for data communication, a modem must be used (see **Modems** later in this section for more details). By using a modem and voice-grade telephone line, one can achieve world-wide digital communication. The telephone companies install and maintain all the media and switching systems necessary. The cost of this type of communication is relatively low because telephone system costs are shared with the general public.

The main disadvantage of using voice-grade telephone lines for data communication is the limited available frequency bandwidth. Voice-grade lines are limited to 300- to 3300- Hz signals. Using complicated combined modulation techniques, such a line can maintain a digital communication rate of up to 9600 bps. Most common modems operate at 2400 bps or less. If higher speeds are necessary, another medium must be used.

Other problems with telephone line-based communication are line noise, inconsistent line quality, and dialing problems.

CURRENT LOOPS

The current loop is one of the oldest data communication techniques in use because it provides an effective communication medium for many applications.

The two main current loop standards are the 60-milliampere and 20-milliampere loops. The 20-milliampere loop is the most commonly used type. Current-loop interfaces provide simultaneous, bidirectional communication in two-point or multi-point networks. They are useful up to a maximum of 5000 feet of hard-wired interface cables.

Current loops are used mostly in industrial systems because the resistance of the communications line does not affect the signal level as much as it does in voltage-based systems. Also, current noise in a cable is less common and easier to deal with than voltage noise. This makes a current-loop communication system less prone to noise problems than a voltage-based RS-232-C communication system.

One disadvantage of a current loop is that it must be wired as a loop. The circuit carrying the current must return to the current source after passing through all devices in the loop. This makes wiring a cable a little more difficult than with RS-232-C.

How A Current Loop Works

In a current loop network, one of the devices must provide the current source and sink for all the other devices incorporated in the loop. Only one device in the loop can be the active current source/sink; all the other devices must be passive switches.

Data is communicated by a switch opening and closing the current loop. Early devices used relays, but transistor switches are more common now. To transmit a logical 1 state, current is allowed to flow in the loop. To transmit a 0 state, current flow is interrupted.

MODEMS AND MULTIPLEXERS

Modems

The word modem means modulator/demodulator. A modem functions just as its name implies. Signals input to the modem are converted to a modulated wave form. Many modulation techniques are used, but the most common are:

Amplitude modulation (AM)
Frequency-shift keying (FSK)
Phase-shift keying (PSK)

Some high-speed modems use a combination of modulation techniques. Once the signal is converted to a modulated form, it can be transmitted over common carrier lines to a matching modem, where it is converted back to its original digital form.

Because modems are often used with RS-232-C local communication lines, be sure to refer to the discussion of the RS-232-C standard. Several of the terms and concepts used in this section are explained there.

Modems are the backbone of digital data communication. They range in function from a simple short-haul (less than a few miles), point-to-point setup, to multi-line, long-haul (global) equipment. There are hundreds of modem manufacturers, and they use a multitude of modulation, error detection, error correction, and local interface schemes.

Be sure to check that the modems on each end of your communication channel are compatible. The few de facto standards for modems are based on Bell system products (see Table 7-6 later in this section). Especially in the higher data rate modems, it is safer to purchase the modems for both ends of the communications channel from the same vendor. If dissimilar modems must be used, be sure to test their compatibility before depending on the data channel.

HOW MODEMS WORK

One of the earliest and simplest modem techniques makes an effective example of how modems work. In a simple two-tone, frequency-shift keying (FSK) scheme, the logical state of the incoming signal is converted to one of two audio frequency tones. The logical 0 state is converted to one tone (a space tone), while the logical 1 state is converted to another tone (a mark tone). These audio-frequency signals are transmitted over a standard phone circuit. A matching detector senses which of the tones is present and regenerates either the 1 or 0 signal state from the audio frequency signal.

The need for higher data transmission rates has brought about more and more complicated modulation schemes in modems. Amplitude modulation techniques are useful between 300 and 1200 bits per second (bps) over voice grade telephone lines. Frequency modulation is used between 50 and 2000 bps.

Because of its higher expense, phase modulation is usually reserved for communications channels requiring 2400 bps on voice grade lines.

When data rates higher than 2400 bits per second are needed on a voice grade line, a combination of amplitude, frequency, and phase modulation can be used. Modems that use combination techniques can achieve up to 9600 bps transmission rates.

If transmission rates higher than 9600 bps are needed, a better line than voice-grade must be used. Most common carriers (including your local phone company) offer lines capable of carrying transmission rates of 56,000 bps or higher. These lines are expensive and should be used only when necessary.

BAUD VS BITS PER SECOND

Bits per second (bps) and baud are sometimes used as if they meant the same thing. However, they are usually not interchangeable units. The baud rate of a line is equal to the bit-per-second rate only if the modulation represents every bit change as a signal change. This is true for simple FSK-type modems, but is rarely true for newer, higher-speed devices. Higher-speed modems usually combine bits into groups of two, three, or even four. For example, a phase-shift modulation modem may represent the bit patterns 00, 01, 10, 11 as the phase shifts of 0, 90, 180 and 270 degrees. Using this technique, a signal-change rate of 1200 baud can support a transmission rate of 2400 bps. Using a combination of phase, amplitude, and frequency modulation, a 4-bit pattern modem can support 9600 bps on a line that can support a 2400-baud signal change rate. This is about the maximum for a good-quality voice-grade telephone line.

FULL- AND HALF-DUPLEX COMMUNICATION

Full-duplex communication means that the devices communicating with each other can transmit at the same time. Half-duplex communication means that only one transmitter is allowed at any one time. In half-duplex communication, after one device is done transmitting, the direction of transmission changes so that the other device can transmit. This is called "turning the line around." An interval of time is necessary between each line turn-around for the line to electrically stabilize and for the modems to adjust to the new direction. This is called "modem training time."

In full-duplex, low-speed communication (1200 baud or less), the line bandwidth can be split up so that data can be sent both ways simultaneously on a single line. At higher speeds, full-duplex communication requires the use of a second line. This is why most high speed, full-duplex modems usually require four-wire leased lines.

SYNCHRONOUS VS ASYNCHRONOUS COMMUNICATION

The main difference between synchronous and asynchronous transmission techniques is the way that the data is blocked. In asynchronous communications, each character starts with a transition from the mark state (binary 1) to the space state (binary 0) and ends with one or more bit times of the mark state. The start sequence is known as the start-bit, and the end sequence is called the stop bit(s). The bit-sampling clock in the receiver synchronizes to each start bit. This means that these clocks are not synchronized between the transmitting and receiving stations; hence, the name asynchronous transmission.

In synchronous communication, a block of characters is transmitted at one time. Each block starts with a specific pattern of bits called a sync character. This character synchronizes the clocks of the transmitting and receiving stations, leading to the name synchronous communication.

Asynchronous techniques are less expensive than synchronous methods, but allow less noise rejection. This is why the higher data rate modems mostly use synchronous techniques.

MODEM STANDARDS

The Bell System and the Consultative Committee for International Telegraphy and Telephone (CCITT) standards are generally followed standards for modems. These are described in Table 7-6 on the next page.

Table 7-6. Modem Standards

MODEM TYPE	DESCRIPTION
Bell 103	A full-duplex, asynchronous, dial-up modem for operation up to 300 bps. May originate or answer the call. Available for direct connect, connection via DAA, or acoustic coupler connections. There are two variations of the 103: the 113A/D (an originate-only modem), and the 113C (answer-only).
Bell 202	A half-duplex, asynchronous modem for operation up to 1200 bps on dial-up lines and up to 1800 bps on leased, C2 or better conditioned lines.
Bell 212	A full-duplex synchronous or asynchronous modem. It operates at either 1200 bps or in Bell 103-compatible mode at 300 bps.
Bell 201	A half-duplex, synchronous modem for operation on either dial-up or leased lines at 2400 bps.
Bell 208	A half-duplex, synchronous modem for operation on either dial-up or leased lines at 4800 bps.
Bell 209	A full-duplex, synchronous modem for operation over leased, D1 conditioned lines at 9600 bps, or as a multiplexer for up to four 2400 bps lines.
CCITT V.26	Same as the Bell 201, except that only four-wire, leased-line operation is allowable.
CCITT V.27	Similar to the Bell 208, but for leased-line, full-duplex operation.
CCITT V.29	A full or half-duplex modem for use at 9600 bps on four-wire leased lines.

Multiplexers

Multiplexers allow several user lines to be carried by a single communication line. They are, in effect, a modem with more than one interface on the user side.

HOW MULTIPLEXERS WORK

Multiplexers use one of two techniques: **frequency division** and **time** division.

Frequency Division Multiplexing (FDM)
This technique assigns each communication channel a separate range of frequencies on the communication line. The frequency range assigned to each channel is separated from adjacent channels by an unassigned frequency range called a guard band. Because of the limited bandwidth of voice-grade telephone lines (300 to 3000 Hz), FDM techniques are generally used only for 300 bps or lower communication speeds.

Time Division Multiplexing (TDM)
The TDM technique allocates a slice of time (called a frame) to each channel according to a rotation scheme. A transmitter with something to send must wait until its assigned frame before transmitting information. Most TDM schemes use character-interleaving; that is, each frame consists of one character from a channel. If a transmitter does not have a character ready to send during its assigned frame, the frame remains empty.

Statistical Time-Division Multiplexer (STDM or Stat-Mux)
STDM is a variation of of the TDM technique. STDM assigns a channel a frame interval based on the past history of the channel. If the channel has been carrying a high character rate, more frames per second are assigned. But if the channel has been idle much of the time, a lower frames rate is assigned. Stat-mux pairs communicate frame assignments with each other so channels don't get mixed up.

SOFTWARE

Software is often the highest cost component of an electronic test, measurement, or control system. By one estimate, seven out of every ten dollars spent on computer systems in the U.S. is spent on software. This is because software for a system is usually custom-designed and implemented, while the other components may be standard, off-the-shelf equipment.

Custom-designed components are always more expensive than standard equipment because the design and implementation costs for custom equipment must be borne by only one installation, while the costs for standard equipment are spread over hundreds or even thousands of installations.

Define what the software is to do before starting the detailed software design. This issue was raised in Sections 1 and 5. When this approach is used, the detailed design proceeds smoothly and without too many changes.

Before doing the detailed software design, make sure that there is not already a commercial package that could do the job. Purchasing a license for an existing software package is usually less expensive than designing and implementing a custom system. The decision to buy or build must be made on a case-by-case basis. Remember that when you custom design and build the software, you must pay not only the initial development costs, but also the long-term maintenance costs.

Detailed Software Design

Detailed software design should be a logical progression from the software specification as explained in Section 6.

Software should be designed in small parts or modules. The decomposition of the software into modules is part of the detailed design process. A module does a small number of specific functions. For example, one module may support the detailed interface with one instrument. Modularity offers the following advantages:

1. Large programs can be written by several people, with each person responsible for one or more modules.

2. Commonly-used routines can be placed in libraries, thus avoiding duplication of effort.

3. Program progress milestones can be based on the completion of sets of modules. This promotes better schedule control.

4. Modules provide a good framework for software testing and verification.

5. Modularity simplifies the design, making the program easier to modify and maintain.

Modules are characterized by the following:

1. A module is a separate compilation in compiled languages.

2. The statements that make up a module are collectively referred to by a descriptive name, called a module name.

3. A module should have a single entry and exit point.

4. A module should return to its caller.

5. A module may call other modules.

6. A module is relatively small in size.

7. A module should not keep a history of what has occurred previously for the purpose of modifying its action or logic path.

8. A module has a single function. This function is the transformation of input to output that occurs when the module is executed.

Modules should be arranged in a hierarchy. Modules that control other modules should come before the modules being controlled. The best way to do this is to construct a hierarchy chart (see Figure 7-41). Start at the top with the highest level control functions and proceed down the hierarchy to the bottom modules. The lowest level modules are those that call no other modules. Hierarchy charts do not show data flow or order of execution; they only show the organization of the modules in relation to each other. A software hierarchy chart is much like an organizational chart for a company: it shows who works for whom, but says little about the functional relationships between the people in the firm.

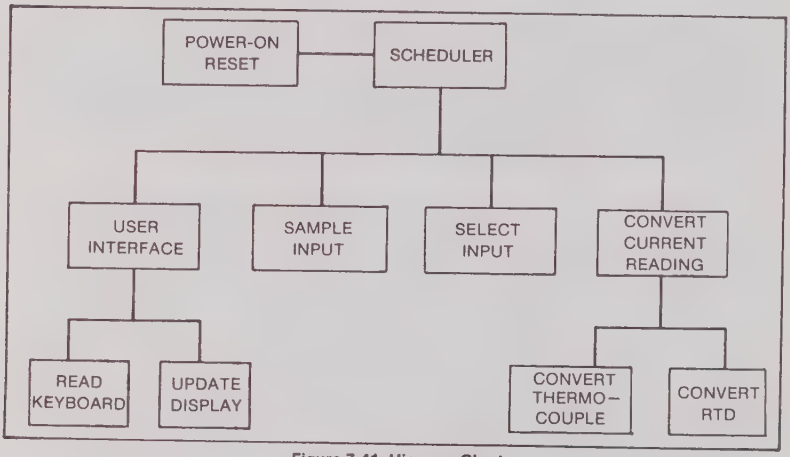


Figure 7-41. Hierarcy Chart

Next, analyze the hierarchy chart to determine the order in which the modules will be coded and tested. The first approach should be a top-down order, but other variations should be analyzed. One of the best approaches is a combination of the top-down approach and an execution-order approach. In general, the following conditions must be met before a module can be coded:

1. Other modules that control the module must already be a part of the running program.

2. Data necessary for operating the module must be available. This data may come from other modules, so either these modules or a simulation of the necessary modules must be available.

In general, plan to code the most complex modules first. There will be fewer unanticipated problems late in the project if this approach is taken. Uncovering problems early allows for adding time or resources to the project during a time when it is less difficult to do so. It becomes more and more difficult to add time and resources to a project as the project proceeds.

Program Design Language (PDL)

The next stage of the detailed design of the software is to do a detailed design of each module. Many techniques are used for to do detailed software design. Flowcharts (see Figure 7-42) have been popular for many years. There is, however, a trend away from flowcharts and toward the use of Program Design Languages (PDL) or Pseudo-Code techniques. This is because flowcharts are difficult to draw, expensive to maintain, and can lead to poor program structure. PDL, on the other hand, can be constructed and maintained easily using a text editor. PDL also encourages good design structure.

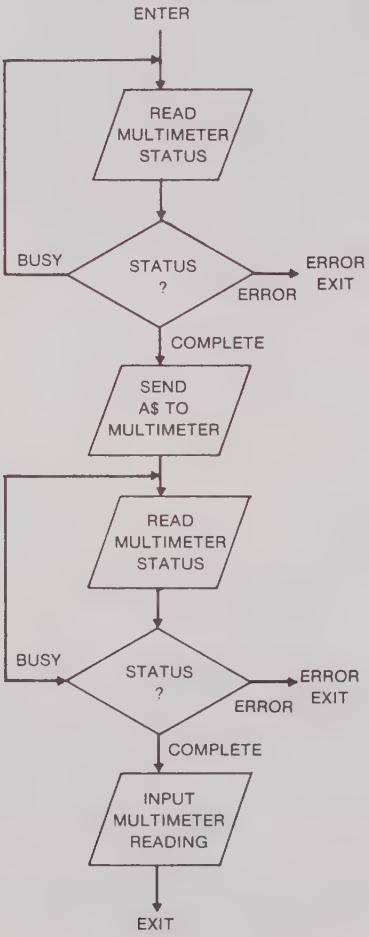


Figure 7-42. Flowchart

In the PDL technique, the control keywords of the language are extracted and used instead of symbols to show the flow of control in the design. The remainder of the description of what the software is to do is written out in natural language. The following example shows this technique using keywords generally available in the BASIC language.

Multimeter Handler Module

```
on call
   A$=command to be sent to the multimeter
on return
   B$=response from the multimeter to the command
   C= error status from multimeter (=0 if no error)

BEGIN multimeter handler module
   REPEAT
      request status from multimeter
   UNTIL multimeter available or in error
   IF multimeter available
      send command in A$ to multimeter
      REPEAT
         request status from multimeter
      UNTIL multimeter status = complete or in error
      IF multimeter status = complete
         request reading from multimeter
         input reading into B$
      ENDIF
   ENDIF
   IF multimeter status = in error
      C=multimeter status
   ELSE
      C=0
   ENDIF
   RETURN
END multimeter handler module
```

In the case of BASIC, the **REPEAT-UNTIL** structure would be actually coded using the following statement sequence:

```
10 statement
20 IF condition THEN GOTO 10
```

Some commonly used PDL keywords are:

1. DO
   statement
   statement
   ...
   ENDDO

2. DO
   statement
   statement
   ...
   WHILE condition

3. LOOP
   statement
   statement
   ...
   UNTIL condition

4. IF condition THEN statement
   ELSE IF condition THEN statement
   ELSE IF condition THEN statement
   .....
   ENDIF

5. CASE
   case 1 : statement
   case 2 : statement
   ....
   ENDCASE

6. LOOP loop count
   statement
   statement
   ...
   ENDLOOP

7. IF condition
   BEGIN
   statement
   statement
   ....
   END

Some rules to follow when doing the PDL type of design are:

1. Use indentation to show program structure.

2. Use descriptive data names. VARIABLE1 and VARIABLE2 are not descriptive enough. If thinking of descriptive names becomes difficult, describe the variables in a header to the module design.

3. Use ENDIF or BEGIN - END to show the beginning and end of an IF-THEN-ELSE structure, even if your implementation language does not have such keywords. This allows the structure of IF logic to be understood by others.

4. Keep the logical flow of the module as simple as possible. Use few levels of nested IF statements.

5. Make sure that error and other such exception conditions are addressed in the design. If such details are left to the implementation phase, some will be missed. The most common software defect (bug) is the mishandling of error and exception conditions.

This seems to be a lot of work to do before even starting to write the actual software. However, this kind of initial preparation can make the actual coding job much easier and result in a better, more maintainable software package. It has been shown that the life cycle costs of software are reduced by using these techniques.

When the detailed design of each of the modules is complete, coding can begin. This next stage is discussed in Section 8.

RACK AND ENCLOSURE SYSTEMS

The mounting and enclosure system for an electronic system is an important component of the system. Racks and enclosures are available in various sizes and shapes from many different vendors. Enclosures are also built to withstand various environments while protecting the electronics components mounted inside. The 19-inch rack has become a common standard within the electronics community. The following paragraphs describe the 19-inch rack standard and discuss some environmental standards for enclosures. Figure 7-43 gives an example of a rack system.

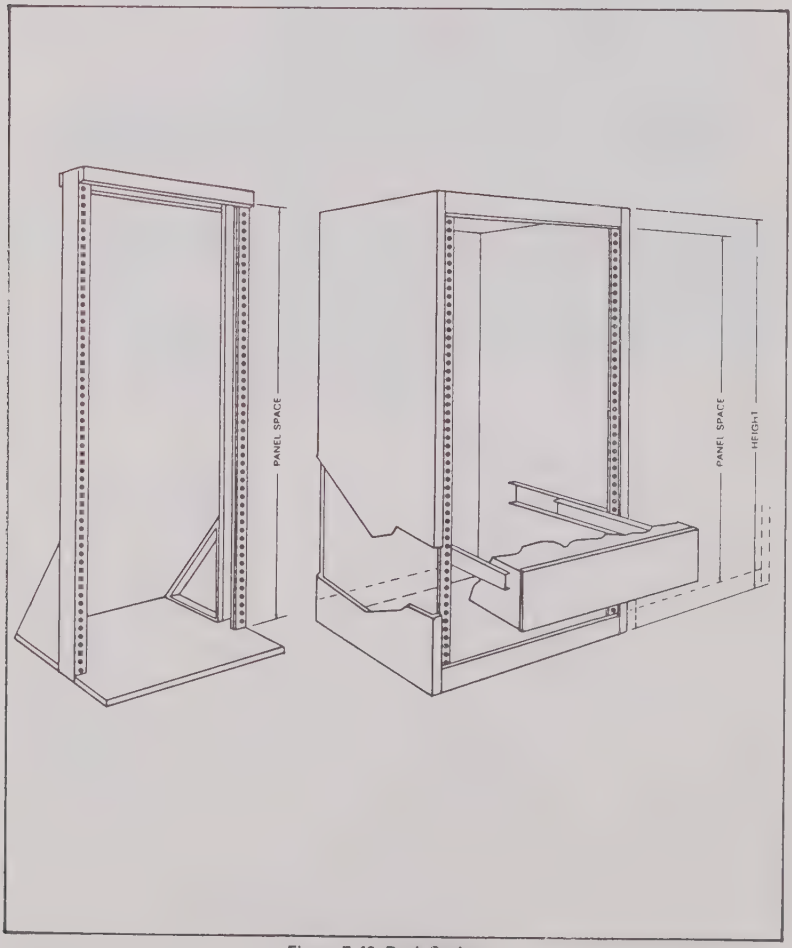


Figure 7-43. Rack System

19-Inch Rack Dimensional Standards

Both the military and industry have standards for 19-inch wide rack systems. (MIL-STD-189 and ANSI/EIS RS-310-C-77). Nineteen inches is the horizontal distance across the width of a panel. The distance between the centers of the panel mounting holes is 18.25 inches (MIL-STD) or 18.312 inches (ANSI/EIS).

Two standard vertical hole spacings are found on the mounting rails of a standard 19-inch rack. In the universal spacing (RETMA) scheme, the top hole is 0.312 inches from the top of the rack, the next hole is 0.625 (5/8 inch) inches down, and the next is 0.5 inches down. The 0.625 to 0.5 inch spacing repeats to the bottom of the rail. In the wide-spacing scheme (Western Electric), the top hole is 0.312 inches down from the top, the next hole is 1.25 inches down, and the next hole is 0.5 inches down. The 1.25 to 0.5 inch spacing repeats to the bottom of the rail.

The ANSI/EIA standard describes 17 different allowable vertical panel space allowances for 19-inch racks, ranging from 17 to 85 inches. The MIL standard specifies 10 different vertical panel space allowances ranging from 17 to 80 inches.

The ANSI/EIA standard describes 12 different individual panel sizes, ranging from 1.7 to 20 inches in height. The MIL standard specifies 18 different panel sizes, ranging from 1.7 to 31.5 inches in height.

Many electronic instruments come with or have optional mounting hardware to fit a 19-inch equipment rack. Make sure that the mounting hardware has the proper width, height, and hole spacing to fit the slot in the rack intended for the equipment. Also, be sure to order enough blank spacer panels from the rack supplier to fill any empty slots in the rack.

Make sure that the equipment rack you select is high enough to mount the equipment with the required spacing between instruments. System designers often don't leave enough air space between instruments for proper cooling. Most instrument specifications give minimum spacing requirements. Review these specifications before designing the rack system.

A common mistake in designing a rack system is to specify insufficient depth to accommodate the instruments and cables. Most of the time, cables connect to instruments by connectors on the rear panel. These cables must make a right angle bend to exit the cabinet through the bottom or top of the rack. There must be enough depth in the rack to accommodate the space taken up by these cable bends when the back door of the rack is closed. Remember, shielded cables may be stiff and require a large radius bend.

Be sure to design your rack system so that when the equipment is mounted the center of gravity is near the bottom of the rack. Racks with most of the weight near the top are dangerous. If heavy equipment must be placed on the top of a rack, make sure the rack is properly bolted to the floor or has stabilizing feet so it won't tip over during maintenance operations.

If equipment is to be mounted on slides, make sure that the rack will not tip over when the equipment is out on the slides. Add stablizing legs if heavy equipment is mounted on rack slides.

Rack Environmental Standards

The National Electrical Code of 1968 (NFPA 70-1968 USAS C1-1968) describes hazardous locations by Class, Group, and Division. The National Electrical Manufacturers Association (NEMA IS 1.1-1977) has defined terminology for classifying equipment enclosures against the NEC-defined environments. If you expect your system to be exposed to hostile environments, review these classifications and select an enclosure that meets the proper NEMA requirements.

NEC Classes

Class I	Combustible material in the form of a gas or vapor.
Class II	Combustible material in the form of a dust.
Class III	Combustible material in the form of a fiber.

NEC Groups

Group A	Atmospheres containing acetylene.
Group B	Atmospheres containing hydrogen, gasses, or vapors of equivalent hazard.
Group C	Atmospheres containing ethyl ether vapors, ethylene, or cyclopropane.
Group D	Atmospheres containing gasoline, hexane, naphtha, benzine, butane, propane, alcohol, acetone, benzol, lacquer, solvent vapors, or natural gas.
Group E	Atmospheres containing metal dust, including aluminum, magnesium, and their commercial alloys, and other metals of similarly hazardous characteristics.
Group F	Atmospheres containing flour, starch, or grain dusts.

NEC Divisions

Division 1	Hazardous mixture is normally present in the area.
Division 2	Hazardous mixture is accidentally present in the area.

NEMA Terminology for Enclosures

NEMA 1 General purpose, Indoor
This type of enclosure is intended to prevent accidental contact with the enclosed apparatus. It is suitable for general-purpose applications indoors where it is not exposed to unusual conditions.

NEMA 2 Drip-proof, Indoor
A drip-proof enclosure is intended to prevent accidental contact with the enclosed apparatus and is so constructed as to exclude falling moisture or dirt. This type of enclosure is suitable for indoor applications where condensation is expected.

NEMA 3 Dust-tight, Rain-tight, and Sleet-Resistant, Outdoor
This enclosure is suitable for outdoor use in specified weather hazards.

NEMA 4 Water-tight and Dust-tight, Indoor and Outdoor
A water-tight enclosure is designed to meet a specific hose test. It is suitable for use indoors and outdoors where washing hoses are used.

NEMA 6 Submersible, Water-tight, Dust-tight, Indoor and Outdoor
This enclosure is used where equipment is subject to occasional submersion in water. The enclosure shall protect the enclosed equipment against a static head of 6 feet of water for 30 minutes.

NEMA 7 Hazardous (NEC Class I, Groups A,B,C or D, Division 1)
Designed to be used indoors and to meet the requirements of the NEC Class, Groups, and Division specified.

NEMA 9 Hazardous (NEC Class II, Groups E, F, or G, Division 1)
Designed to be used indoors and to meet the requirements of the NEC Class, Groups, and Division specified.

NEMA 10 Bureau of Mines Explosion-proof
Designed to meet the U.S. Bureau of Mines requirements for explosion-proof enclosures. Suitable for use in gassy coal mines.

NEMA 12 Industrial Use, Dust-tight and Drip-tight, Indoor
Designed for use indoors in industries where it is desired to exclude dust, lint, fibers, oil seepage, or coolant seepage.

NEMA 13 Oil-tight and Dust-tight, Indoor
Designed for use indoors as enclosures for limit switches, foot switches, pushbuttons, selector switches, pilot lights, etc. Protects against lint and dust, seepage, external condensation, and spraying of water, oil, or coolant.

The system will usually be in an non-hostile environment like a control or equipment room. When hostile environments are encountered, it is sometimes more cost effective to build a protective room around the equipment rather than using expensive enclosures.

Rack Cooling

A rack-cooling system may consist of a number of simple vents or a complex system of blowers, ducts, and refrigeration units. To calculate the amount of cooling necessary in the rack, use these steps:

1. Calculate the volume of air required by the formula:

   Q = SF x (3.17 x p) / (TM-TI)

   Where:

   Q = Volume of air in cubic feet per minute (CFM) (air density assumed to be 0.075 lb/cu ft)

   SF = Safety factor (at least 1.25)

   p = Power in watts to be dissipated

   TM = Maximum allowable temperature in rack.

   TI = Inlet air temperature

2. Compensate **Q** if air density is not 0.075 lb/cu ft

   QN = Q x (459.7+TI) / (1.325 x b)

   Where **b** = barometric pressure in inches of mercury.

3. Compute the inlet areas **a**.

4. Calculate the rate of airflow.

   r = QN/a

   Where **r** = airflow rate in feet per minute

If the required airflow rate is low, natural convection may be all that is required. Fans deliver air velocities in the range of 500 to 1500 feet per minute. Blowers are used in the 1500 to 5000 feet/minute range.

Some general rules on rack cooling are listed below.

1. Establish a upward airflow through the rack. Hot air rises, aiding an upward airflow.

2. Pressurize the cabinet with fans and blowers rather than pulling the air out. A slightly higher pressure in the rack keeps dirt and dust out of the equipment.

3. Separate the intake from the outlet by as much space as possible. This keeps the hot outlet air from being recycled through the rack.

4. Over-design the cooling system to allow for system expansion.

SECTION 8

IMPLEMENTING YOUR SYSTEM

CONTENTS

Introduction 8-1
Purchasing System Components 8-1
Building Custom Components 8-2
Writing Applications Software 8-3
Systems Integration 8-4

INTRODUCTION

Once the detailed design of the system is complete, it is time to implement, or build, the system. The issues that need to be addressed during this phase of system development are discussed below.

PURCHASING SYSTEM COMPONENTS

The process of purchasing system components should have been started at the time that the system specification was complete. At that time, you should have started working with several equipment vendors on a recommended system configuration. This effort continues during the detailed design phase. Near the end of the detailed design phase, each vendor should be required to submit a formal quote for the equipment they are proposing to be included in the system.

The quote should include not only the purchase price of the equipment, but also an indication of its life-cycle cost. The life-cycle cost includes the purchase price, maintenance costs, the cost of periodic calibration, and the cost of periodic replacement of equipment with limited lifetimes. The purchase decision should be based on the life-cycle cost, not just on the purchase cost.

Another factor that should be considered is the overall impact on the system of including a specific piece of equipment. Take a look at the cost of purchasing or developing software and communication interfaces to control the specific piece of equipment. Sometimes it makes more sense to purchase a more expensive device that is easy to interface than to purchase a less expensive device that has a complex or non-standard interface.

The experience of the design and implementation personnel must be taken into account. If all your people are trained on a specific piece of equipment, it makes sense to continue to purchase that type of equipment. However, this must be a balanced decision. Many times the cost of retraining is overwhelmed by the savings brought about by newer or different equipment.

When you purchase a systems component, you not only purchase the equipment, but you also purchase a small portion of the company itself. You may have to depend on the service and support offered by the vendor for the continued operation of your system. Be sure to investigate each company submitting a quote. Look into their reputation for support and service. Ask for references, and call other users of the company's equipment to see if their experience with the company has been good. Make sure that the company's financial situation is secure. If they go out of business, you will be left with no support for your equipment.

Make sure that the documentation package for each system component is available and complete. Minimum documentation packages for electronic devices should include a complete instruction manual and a service manual that includes a schematic. Each available interface should be well-documented. There should be a troubleshooting guide included in the service literature. A good troubleshooting guide can eliminate many unnecessary service calls and system down time.

BUILDING CUSTOM COMPONENTS

You should build your own system components only after making a careful analysis, and then only as a last resort. The product development cycle of electronics manufacturers can range between one and five years. Much of this time is used to test the product to ensure compliance with government and industry standards. System builders rarely invest the resources and time necessary to produce a system component that is competitive in cost and performance with those produced by the equipment manufacturers. So it is usually better to purchase the component if one that does the job is commercially available.

Most custom component construction by systems builders is limited to cabling and panels. The rules that apply here are "neatness counts" and "safety first." Be neat when dressing cables and labeling them. Remember, you may have to find a particular wire again during a maintenance procedure. Stick-on labels or color-coded wires can pay for themselves many times over during the life of the product.

Make sure that the wires in the system meet all voltage standoff insulation requirements. The conductors will carry not only the expected signals, but also any common-mode voltages picked up from transducers, test points, etc. These common-mode voltages may be many times larger than the actual signals. For example, a thermocouple may output a signal of only a few millivolts, but if it is welded to a bus bar, the common-mode voltage on the lead wires may be hundreds of volts.

CAUTION

> If wire insulation is insufficient to withstand the common-mode voltages, a failure may occur that could endanger operators or destroy equipment.

All mounting panels should be well grounded. Some operating or failure conditions can cause high voltages on the cases of electronic equipment. Mounting panels should be grounded well enough so that these voltages do not present a safety problem to system operators.

WARNING

> All metallic parts which are operator-accessible should be grounded adequately. Use large enough wire to ensure operator safety in the event of a failure condition.

Don't assume that panel mounting screws or bolts will ground a panel. Paint and corrosion around mounting hardware can cause poor connections between the panel and other pieces of hardware. Use separate grounding straps whenever possible. Besides being inherently safer, grounded panels also serve as an electrostatic noise shield. This may be important if the system has to exist in an electrically noisy area.

WRITING APPLICATION SOFTWARE

The preparation of custom application software is often the largest task of the system builder. The preparation for writing the software started during the specification process and continued as a major part of the detailed design. At this point the writing process should consist of translating the detailed software design into the chosen computer language. It is poor practice to design the software while it is being written. Software produced this way usually cannot be maintained by anyone other than the programmer.

The choice of a language in which to implement the application software is affected by many factors. Choose the language to fit the application. For example, Interpreted BASIC is a good language for relatively short, I/O intensive applications. FORTRAN, on the other hand, is a good choice for math-intensive or long programs. COBOL is optimized for data management and financial software. ATLAS is intended for use in large Automatic Test Systems.

The facilities available can also influence the choice of an implementation language. The computer that you are using to develop the software may support only a limited number of languages. Also, a particular language may have better support within your organization.

Training is a definite factor in the choice of a computer language. You should choose a language that most people on the project know. A lot of time can be wasted bringing everyone up to speed on a new programming language. If everyone knows an appropriate language, it makes little sense to switch.

Once a language is chosen, the process of writing the software in a compiled language is as follows:

1. The programs are translated from the design language into the implementation language. The text of the programs is entered and edited using a text editor. Each module is placed in a separate file. These files are called the source code.

2. Each module in the high-level language is compiled into an object file by running the compiler program. Errors flagged by the compiler are fixed and the module is recompiled. This step is repeated until the module can be compiled without errors. Detailed source code listing files are often produced as a result of compilation.

3. Each module in assembly language is assembled into an object file by running the assembler. Errors picked up by the assembler are fixed and the assembly repeated. Source code listings showing the resulting machine language are often produced by the assembler.

4. All modules in a program are linked to one another and to any necessary vendor-supplied libraries by executing the linker program and naming each object file and library. Some linkers require that the object files be named in a particular order. The file output from the linker is usually the runnable program.

5. The program is run and any problems found are fixed. A debugging tool is often used to aid in the initial program debugging process. Problems found in this process are fixed in the initial source code.

6. Any modules changed during debugging must be recompiled (step 2) or reassembled (step 3) and the entire program relinked (step 4) before the changes become a part of the program.

7. Steps 2 through 6 are repeated until no more problems are found.

The process of writing the software in an interpreted language is as follows:

1. The design is translated into the implementation language. Modules become separate sections of the program, but not separate files. A text editor that is a part of the language is usually used for this entry and editing process. Some simple errors (like typing errors) are usually detected at the time that the program statements are entered.

2. The program is run and errors are detected. Debug aids are usually built into the language to aid in the process of finding problems with the program.

3. When problems are fixed in the source code, the program is immediately rerun.

4. Steps 2 and 3 are repeated until no more problems are found.

As you can see, the process of debugging code in an interpreted language is much shorter than that for a compiled language. However, since there is limited modularization of the code in an interpreted language, large programs are difficult to maintain. Writing large programs in a compiled language is usually more efficient.

BASIC is a popular language for implementing systems software. However, because BASIC has been available as only an interpreted language, it has been difficult to build large programs in this language. To counteract this disadvantage, several computer vendors have developed versions of BASIC that have both an interpreter and a compiler. You can develop code modules in BASIC using the interpreter and then compile and link them together into large programs.

SYSTEMS INTEGRATION

Systems integration is the phase in the systems development process where the systems components are made to work together. A period of time during the project must be reserved for this activity.

System components often interact in ways that are difficult to foresee during definition and design phases. Such interactions are discovered and compensated for during the systems integration phase. Many of these interactions are caused by EMI from one system component affecting another component. For example, the high-voltage power supply in a video display terminal may cause noise problems in a nearby multimeter.

The FCC has issued regulations on noise emissions by electronic devices. While these regulations may help minimize these type of unwanted interactions, they will never completely eliminate them. Shielding may have to be added during the systems integration phase to solve these types of noise problems.

Inadequate cooling capacity in the system mounting racks or enclosure can cause hot spots and general overheating of the systems components. Fans on racks or enclosures must be sized so that all system components have enough cooling air. Also check that enough circulation space has been left around the components and cables in the racks or enclosures.

Overheating problems may not occur until the first really hot day after the system is installed, so it is best to design the cooling system for a 20% to 30% higher capacity than the sum of the needs of the system components.

Other typical system integration problems include:

1. Cable routing problems that result in excessive noise pickup.

2. Line power outlet placement and capacities.

3. Timing problems in the system control computer.

4. Interface inconsistencies with other in-place computer systems that must send or receive data.

5. Inconsistencies between the documentation and the actual operation of a system component.

6. Subtle communication system and protocol incompatibilities between system components.

7. Inaccessible controls or obscured displays that result in the relocation of system components.

8. Unplanned interactions between software modules.

SECTION 9

TESTING YOUR SYSTEM

CONTENTS

Introduction 9-1
Informal Testing 9-1
Element Tests 9-1
Functional Tests 9-2
Acceptance Tests 9-3

INTRODUCTION

Testing is a continuous process that starts as soon as the first system components are hooked together and continues throughout the life cycle of the system. The most active period of testing is during and immediately after the implementation or integration of the system software.

The ultimate goal of testing should be to find the defects that exist, not to prove that the system is free of defects. This subtle difference in attitude makes a lot of difference in the ultimate quality of the system. If the goal of testing is to prove that the system is defect-free, testing will not be as complete. If, however, the attitude is taken that there are defects to be found, and the goal is to find them, all aspects of the system operation will be tested.

The test plan for your system should be written during the system implementation phase. Base the test plan on the detailed system specifications and designs. Run the tests according to the test plan. If possible, implement the tests in computer software so that rerunning the complete test plan is simplified. Keep a log of the defects that are found and fixed. The proper maintenance of an error log can reduce labor later in the testing process.

The testing process is divided into four distinct phases. The remainder of this section describes these phases in detail:

- Informal testing
- Element tests
- Functional tests
- Acceptance tests

INFORMAL TESTING

Informal testing occurs as the components of the system are implemented and integrated. For example, a programmer will try out a code module as soon as it is programmed. This testing does not follow any formal test plan and is intended to test for obvious errors. Maintaining a log of these informal tests is not necessary. Most defects are found during this informal testing phase. Only the most subtle defects, or defects that are caused by the interactions between system components, will be missed by informal testing. However, it is these subtle defects that cause most of the problems. To find these defects, a more formal testing procedure must be followed.

ELEMENT TESTS

Element tests are formal tests done on individual components of the system to determine if the component specifications are met. Element tests are often omitted because proper, formal element tests require a lot of resources. Hardware element tests require the development of special test hardware and software. Software element tests require the development of special software to simulate the environment in which the software module will be running.

Element testing is done when there must be a high degree of confidence that each system component and software module is performing according to its specifications. The specifications produced by commercial hardware vendors are usually sufficient proof of compliance with the system specification. Purchased software can also be treated in this manner. On the other hand, user-built hardware and software can benefit greatly from element testing.

To do an element test, first write a detailed test plan. This plan is based on the system specification for the specific component. A specific test case must be developed for each individual requirement stated in the specification. The test plan should be written by someone other than the designer or implementer of the system component. For example, the designer and implementer of a software module should not write the test plan for the module.

The next step is to build the test system necessary to execute the test plan. The resources necessary for an element test range from simple software packages to elaborate hardware/software systems. Remember, the tests should simulate the real conditions that the system will encounter during operation. For example, if the system will operate in a high-vibration environment, a shaker table should be used to simulate this during testing.

The last step is to run the tests and evaluate the results. If the element does not pass the test, either modify it until it does pass or else modify the system specification to delete the unmet requirements. Any modifications to the system specification should be carefully reviewed; after all, there was probably a good reason for the requirement in the first place.

Element tests should be repeated whenever there is a change to the component in question.

FUNCTIONAL TESTS

Functional tests are done on the entire system or its major subsections to determine if the requirements stated in the system specification are met. Functional tests are sometimes called "black box" tests because the system is treated as a whole, rather than being broken down into components.

To do a functional test of the system, first write a detailed test plan. This plan should include test cases for each of the functions of the system as stated in the system specification. Next, the system should be placed in an environment that simulates (or is) the actual expected operating conditions. A simulation of the normal system inputs and outputs should be constructed. For example, a process-control system can be tested using an analog computer simulation of the actual process.

Last, run the functional tests and analyze the results. Fix any defects that are found and then repeat the entire test. This process is repeated until no more defects are found. Keep a log of each defect found during the test process; record the fix for the defect, who fixed the defect, and when it was fixed.

Defects that require a change to the specification should be carefully reviewed. Changes to a system specification during the test phase should be done carefully and should be well documented. Specification changes sometimes involve negotiations with the end users and others involved in the system development.

ACCEPTANCE TESTS

Acceptance testing is a special case of the functional test. It is usually a slightly simplified version of the functional test performed in the presence of the system user or purchaser. The acceptance test should demonstrate that the system operates according to the system specifications. The successful completion of the acceptance test usually means that responsibility for the system passes from the designer and implementers of the system to the system maintenance organization.

SECTION 10

INSTALLING YOUR SYSTEM

A system that is well designed and implemented is usually easy to install. However, during installation you will find all the subtle details that were missed during the previous phases.

Take care to properly package a system that must be shipped to the installation site. Check with the vendor of the system components for packing instructions. Some vendors require that certain precautions be taken; otherwise, the warranty for the equipment will be canceled. Electronic equipment should be handled and shipped by qualified people. Several moving companies in the U.S. offer special electronics moving services.

The delivery of the system components to the installation site should be fully scheduled to ensure that all the equipment is on site at the necessary time. Make sure that transit times are taken into account when working up a delivery schedule.

Be sure that the installation site is ready before delivery of the system begins. Delicate electronic equipment should not sit in some cold and damp storeroom, waiting for the installation site to be ready.

The system components should be installed according the plan in the system specification. Make sure that all cables are well labeled and that the cable routing is clean. Don't make a jumble of wires in the cable trays or under the floor. Remember, someone is going to have to maintain the system.

Don't turn the system power on until everything has been checked. Make sure that no printed circuit boards in the system components have come loose from their connectors. Check each cable connector for tightness. Make sure that all cooling fans are plugged in and working. Clean up the area. Move all packaging material, boxes, cable ties, loose wire, plastic bags, spare parts, etc, out of the area.

Power up the system components one at a time, following the instructions supplied by the manufacturers. In this way, if a circuit breaker or fuse opens, it will be obvious which component has the problem. If a fuse or circuit breaker opens during the initial power up, don't just replace the fuse or close the breaker. Try to determine what's wrong before trying again. Sometimes a fuse or breaker will protect the instrument once, but you may have a destroyed instrument on your hands if you push your luck.

Once the entire system is powered up, an installation test should be done. This test is usually the acceptance test (see Section 9), but can be an abbreviated version of the acceptance test.

SECTION 11

MAINTAINING YOUR SYSTEM

System maintenance is usually the responsibility of a different organization than the one that defined, designed, and implemented the system. This leads to a common problem encountered in systems work: the unmaintainable system.

Unmaintainable systems usually result from taking shortcuts during the definition or design phases. Detailed specifications and design documentation are the best source of information for maintenance tasks.

For example, a software defect is found after the system is installed and working. The software designer/implementer has left the company. If no detailed design information is available, the system maintainer must try to determine what the problem is and how to fix it using only the code listings. Even if the source of the problem can be found, the fix will usually cause even more problems.

In general, small local problems can be fixed based on the information in a well-commented software source listing or system schematic. The design documentation is essential if the problem requires changes to several interacting areas of the software or system.

Design documentation that is passed on to the maintenance organization should include:

1. The complete system specification.

2. Detailed design documentation, including the detailed software design, hardware schematics, hardware design notes, and cable diagrams.

3. The complete set of test procedures and the acceptance tests.

4. The installation plan and diagrams.

5. A complete set of service manuals for the commercial instruments included in the system.

6. Vendor-supplied diagnostic programs.

This documentation should be kept in a central storage area that is accessible to the maintenance staff. If possible, any special hardware developed for use during the system test phase should be kept for possible maintenance use.

Each time that a substantial change is made to the system, the system test procedure or acceptance test procedure should be rerun. This continues to verify that the system is operating according to the original system specification.

Maintain a log detailing all maintenance procedures and engineering changes performed on the system. The log should list a description of the change, what system components were affected, the person responsible for the change, the date, and the time. This information enables system management and maintenance personnel to determine what the configuration of the system is at any time.

INDEX

4-wire measurement technique, 7-5
19-inch rack dimensional standards, 7-85
ATLAS, 5-17, 8-3
ATN line, 7-39
acceptance tests, 9-3
Acceptor Handshake (AH), 7-40, 7-46
Ampere (amp), 7-6
Amplitude Modulation (AM), 7-72
analog
    communication, 5-5
    indicators, 7-30
    -to digital conversion (A/D), 7-2
application
    expert, 4-1
    level, 7-66
    programming, 5-22
assemblers, 5-16, 5-19
asynchronous communications, 7-74
Attention (ATN), 7-39
Automatic Test Equipment (ATE), 6-14
autoranging, 6-4
autozero, 6-6
BASIC, 5-17, 8-3, 8-4
balanced (differential) voltage signal, 7-59
baseband LAN's, 7-70
Baud, 7-73
Baud vs. bits per second, 7-73
Bell MODEMs, 7-75
Bits Per Second (BPS), 7-73
board level testers, 6-14, 6-15
braid shields, 5-9, 5-15
bridge configurations, 7-20
broadband LAN, 7-70
building custom components, 8-2
burden voltage, 6-4
bus network, 7-69
cabling requirements, 5-1
calibrators and standards, 6-7
Celsius (or Centigrade) scale, 7-9
CCITT Standards, 7-75
Clear to Send, 7-57
COBOL, 8-3
combination shields, 5-15
common mode noise, 5-7
common mode rejection (CMR), 5-13, 6-4
communications, RS-232-C, 7-53
communication techniques, 5-5, 6-1
compiler, 5-17, 5-18
compliance voltage, 7-7
component testers, 6-14
compressive strain, 7-17
computer data networks, 7-65
computer front-ends, 6-20
conductance, 7-6
consultants, 4-2
construction and engineering firms, 4-2
contention approach, 7-69
control systems, 2-1, 2-3
Controller (C function), 7-38, -46, -51
cooling air, 6-2, 7-88
Costs and Staffing, 4-3
counters, 6-4, 6-5
current, 6-3, 7-6, 7-25
    loops, 7-71
    shunt, 7-6
custom system development, 4-3
data base 7-31
data base management systems, 5-19, 7-31
data coherency, 5-21
Data Communication Equipment (DCE), 7-54
data highways, 7-65
data link level, 7-66
data loggers, 6-20
data management, 5-20, 7-31
Data Set Ready, 7-57
Data Signal Rate Selector (DCE Source), 7-58
Data Signal Rate Selector (DTE Source), 7-57
Data Terminal Equipment (DTE), 7-54
Data Terminal Ready, 7-57
Data Transfer Control, 7-46
Data Valid (DAV), 7-39
datalogger and computer front-ends, 6-20
Defining The Function of Your System, 3-1
definition phase, 3-1
definition of a system, 1-1
design review, 5-23
detailed block diagram, 5-1
detailed software design, 7-77
Device Clear (DC function), 7-43, -46, -50
Device Trigger (DT function), 7-46, -51
device addresses, 7-41
development cost, 4-3
digital communication, 5-5
    techniques, 6-1
digital to analog conversion (D/A), 7-22
direct synthesis, 7-25
dynamic strain, 7-20
EOI, 7-39
electric field (or electrostatic) noise, 5-6
Electrical Interface Type (E function), 7-46, -52
electrical
    noise, 5-6
    power, 7-9
    distribution, 6-2
    standards, 6-7
electromechanical relay, 6-11
electromotive force, 7-1
electronic mail, 5-16, -20
electronic test, measurement, and control systems, 1-1
element tests, 9-1
End Or Identify (EOI), 7-39
environmental considerations, 6-1
error, 5-6
extension wire, 7-14
electromagnetic interference (EMI), 5-6
electrostatic noise, 5-9
Fahrenheit scale, 7-10
Field Effect Transistors (FET), 6-11
field service equipment, 6-14, -18
floating measurements and guarding, 5-10
floor plan, 5-1
flowcharts, 7-29
foil
    shields, 5-15
    wrappings, 5-9
formal review, 5-23
format conversion utilities, 5-16, -20
FORTRAN, 5-17, 8-3
four-terminal ohms, 6-4
Frequency Division Multiplexing (FDM), 7-76
frequency, 6-5, 7-7, 7-25
    measurement, 7-7
    synthesis, 7-25
Frequency Shift Keying (FSK), 7-72
full and half duplex communication, 7- 73

functional tests, 6-16, 9-2
    equipment, 6-14
gate time, 7-7
gauge factor, 7-20
Go To Local, 7-43
ground current loops, 5-6, -10
grounded junctions, 7-14
Group Execute Trigger, 7-43
guard, 5-10, 6-4
half-duplex communication, 7-73
hierarchy chart, 7-78
High Level Language (HLL), 5-17
Hooke's law, 7-19
host system, 5-16
IEEE-488 Bus communications, 7-31
    control computers, 7-35
    interface circuitry, 7-36
IFC line, 7-39
ISO reference model, 7-65
implementation
    language, 8-3
    strategy, 5-1
implementing your system, 8-1
in-house system development, 4-1, -3
indirect frequency synthesis, 7-25, -27
inductive pickup, 5-6, -9
industrial RTDs, 7-16
informal testing, 9-1
input and output points, 5-1
installation test, 10-1
installing your system, 10-1
instrument controllers, 6-12
Interface Clear (IFC), 7-39
internal review, 5-23
International System of Units (SI), 6-9
interpreter, 5-16, -17
isolation transformer, 5-10
Kelvin
    connection, 7-5
    scale, 7-10
Light Emitting Diode displays (LED), 7-29
line voltage and frequency, 6-2
linkers, 5-16, -19
Liquid Crystal Displays (LCD), 7-29
Listener (L), 7-38, -46
Listener and Extended Listener, 7-48
Local Lock Out, 7-43
Local area network (LAN), 7-65
Local secondary standards, 6-9
machine languages, 5-17
matrix switches, 6-11
measurement, 7-1
    systems, 2-2
modem, 7-53, -70, -72
    and multiplexers, 7-72
    standards, 7-74
modularity, 5-17, 7-77
modulation techniques, 6-6
Modulator/Demodulator, 7-72
modules, 7-77
mounting system, 6-1
multimeters, 6-3
multiplexers, 7-76
My Listen Address, 7-43
My Secondary Address, 7-43
My Talk Address, 7-43
NBS standards, 6-9
NEC classes, divisions, and groups, 7-86
NEMA enclosure standards, 7-87
network
    channel control, 7-69
    level, 7-66
    physical implementation, 7-70
    topologies, 7-67
noise
    pickup, 5-6
    rejection specifications, 5-13
    sources, 5-6
    solutions, 5-9 thru 5-12
normal mode noise, 5-7
Normal Mode Rejection (NMR), 5-13, 6-4
normal stress, 7-19
Not Data Accepted (NDAC), 7-39
Not Ready For Data (NRFD), 7-39
OEMs, 4-2
Ohm, 7-4
Ohm's law, 7-4
operator interfaces, 5-4
overrange, 6-4
Pascal, 5-17
PBX, 7-70
Planning For System Design and Implementation, 4-1
Parallel Poll (PP function), 7-46, -50
    Configure, 7-43
    Disable, 7-43
    Enable, 7-43
    Response, 7-43
    Unconfigure, 7-43
period, 6-5, 7-8
Phase Shift Keying (PSK), 7-72
physical level, 7-66
Poisson strain, 7-17
polling approach, 7-69
power, 7-9
power line
    fade and drop-out, 5-9
    noise, 5-6, -9
presentation level, 7-66
prime contractor, 4-2
Private Branch Exchange (PBX), 7-72
productivity, 4-4
Program Design Language (PDL), 4-4, 7-79
programmable power supplies, 6-12
proportional limit, 7-19
protective ground, 7-57
pseudo-code techniques, 7-79
purchasing the system components, 8-1
quote, 8-1
REN, 7-39
RS-232-C, 7-53
RS-422-A, 7-59, -60
RS-423, 7-59
RS-449, 7-59
RS-485, 7-59, -63
RTDs, 6-18
rack
    and enclosure systems, 7-84
    cooling, 7-88
    environmental standards, 7-86
    slides, 7-86
    system, 6-1
Radio Frequence Interference (EMI), 5-6
radio frequency noise, 5-9
Received Data, 7-57
Received Line Signal Detector, 7-57
Receiver Signal Element Timing (DCE Source), 7-58
Recognizing the Need For a System, 1-2

Remote Enable (REN), 7-39
Remote/Local (RL function), 7-46, -50
Request to Send, 7-57
resistance, 6-3, 7-4, -25
    sources, 7-25
    temperature detectors (RTD), 7-15
    temperature measurement, 7-15
resolution vs. reading speed, 7-8
Ring Indicator, 7-57
ring network, 7-68
scanners and matrix switches, 6-10, -11
scheduling tools, 5-16, -20
Secondary Clear to Send, 7-58
Secondary Received Data, 7-58
Secondary Received Line Signal Detector, 7-58
Secondary Request to Send, 7-58
Secondary Transmitted Data, 7-58
Selecting Systems Components, 6-1
self-heating error, 7-6
semiconductor temperature measurement techniques, 7-17
sensor, 7-1
Serial Poll, 7-47
    Disable, 7-43
    Enable, 7-43
Service Request
    SR function, 7-46, -49
    SRQ, 7-39
session level, 7-66
shear stress, 7-19
shearing strain, 7-17
shielding
    and guarding, 5-9
    cables, 5-15
signal
    ground, 7-57
    quality detector, 7-57
    generators, 6-6
    sourcing, 7-22
software, 5-16, 6-2, 7-76, -77
    design, implementation, and test, 4-4
    development and operating environment, 5-16
    development facility, 4-3
Source Handshake (SH), 7-46
spectral purity, 6-6
standards
    19-inch rack, 7-85
    Bell Modem, 7-75
    CCITT, 7-75
    electrical, 6-7
    EIA, 7-53
    IEEE-488, 7-31
    local secondary, 6-9
    Bell modem, 7-75
    NBS, 6-9
    NEC, 7-86
    NEMA enclosure, 7-87
Standard Platinum RTDs (SPRTs), 7-15
star network, 7-67
static strain, 7-20
Statistical Time Division Multiplexer (STDM or Stat-Mux), 7-76
strain, 7-17
strain gauge bridges, 7-20
stress, 7-17
structured
    design techniques, 4-4
    implementation, 4-4
switches and switch controllers, 6-10
switching UPS, 5-10
synchronous communication, 7-74
synchronous vs. asynchronous, 7-74
system
    component, 1-1
    component vendors, 4-1
    definition, 3-1, 5-1
    development overview, 1-2
    development cost, 4-3
    integration, 8-4
    integration problems, 8-5
    goals and objectives, 3-1
    houses, 4-2
    maintenance, 11-1
    multimeters, 6-3
    needs analysis, 3-2
    responsibility, 4-2
    specification, 5-1
Take Control, 7-43
Talker (T), 7-38, -46
Talker and Extended Talker, 7-47
target system, 5-16
Telephone and Other Carrier Systems, 7-70
temperature, 7-9
temperature coefficient, 6-4
tensile strain, 7-17
terminals, 6-13
tertiary level, 6-9
test plan, 9-1
test systems, 2-1
Testing Your System, 9-1
text editors, 5-16, -19
The Definition Review, 3-3
thermocouple, 6-18, 7-10
    junctions, probes, and wires, 7-13
    measurement error sources, 7-15
    temperature measurement, 7-10
    Types C, E, J, K, R, S, and T, 7-12
thermometers, 6-18
third parties, 5-1
    systems firms, 4-1
Third Party Organizations, 4-2, 5-1
Time Division Multiplexing (TDM), 7-76
time interval measurements, 6-5
token passing approach, 7-69
totalize, 6-5
traceable calibration, 6-7
transconductance amplifier, 7-25
transducer, 7-1
transfer and inter-laboratory standards, 6-9
Transmit Signal Element Timing, 7-58
Transmitted Data, 7-57
transport level, 7-66
trigger
    level, 7-7, -8
    sensitivity, 6-6
twisted pair signal wires, 5-9
ungrounded junctions, 7-14
uninterruptible power supply (UPS), 5-10
Unit Under Test (UUT), 2-1
Unlisten, 7-43
Untalk, 7-43
user interfaces, 5-4, 7-28
vacuum fluorescent displays, 7-30
vendors, 5-1
Video Display Terminal (VDT), 6-13, 7-28
voltage, 6-3, 7-1, -22
wrapped wire shields, 5-15
writing application software, 8-3

EXAMPLE OF PERFORMANCE VERIFICATION SOFTWARE FOR 544XX

Deriviation

The following pages contain a listing of a user developed performance verification procedure for a Fluke Model 5440B Direct Voltage Calibrator. It has not yet been translated to run with the 7411A. This procedure is derived from the information found in Section 3 of the 5440B's Service Manual.

Line by Line Synopsis

Lines 1.001 through 1.020 provide setup information for the procedure. The procedure utilizes user supplied low thermal EMF test cables, referred to as PVC's # 1, 2, 3 and 4 in the procedure as well as user supplied dual banana socket to dual spade lug low thermal EMF adaptors.

Lines 1.021 through 1.026 are used optionally when the 752A needs to be self-calibrated. Line 1.025 calls the 752A SELF-CAL procedure. The 752A SELF-CAL procedure, listing included, is very terse and requires the operator to use the 752A instruction manual rather than being prompted by the procedure itself.

Lines 1.027 through 1.039 illustrate how the MEMI and MEME FSC's are used to store reference voltages of 10V, 0.1V, 1.0V, 20V, 100V and 1000V, respectively, as derived from the actual value of the 10V output voltage of Fluke Model 732A Solid State 10V Reference Standard.

Lines 1.040 through 5.009 invoke the internal calibration of the 5440B and then verify its 0.1V, 1.0V, 10V, 100V and 1000V outputs on the appropriate ranges. The use of the RSLT = FSC formats the results printout by placing a blank line between the test results for each value tested.

Lines 6.001 through 6.027 test the 20V output of the 5440B. In this procedure, this test occurs after the other values are tested in order to reduce the connection time and to preserve the connection of the 720A for use in another procedure that the user intends to run immediately after the 5440B has been tested. Lines 6.006 through 6.013 are used optionally when the Fluke Model 720A Kelvin-Varley divider needs to be self-calibrated. As in the case of the 752A, the CALLed 720A SELF-CAL procedure, listing included, is very terse and requires the operator to use the 720A manual.

A four terminal connection is made to the 720A's 1.0 INPUT because the series resistance of the wires that bring the 5440B's output to the A123's Test Interface Panel is about 0.2 ohms. This amount of resistance represents a 2ppm error when compared to the 720A' 100k Ohm input resistance.

Lines 7.001 through 7.007 test the 5440B's load regulation. The EVALuation of line 7.007 requires the operator to remember what happened when he or she pressed the ADVance key in step 7.006 and to recall this information in response to the prompt of step 7.007.

Lines 8.001 through 8.0012 end the procedure. Note that a blank HEAD is used at line 8.012. The blank HEAD erases the 1722A's CRT display.

INSTRUMENT: 5440B PERFORMANCE VERIFICATION

DATE: 12-Apr-86
AUTHOR: F. CAPELL
REVISION: 0

ADJUSTMENT THRESHOLD: 70%

NUMBER OF TESTS: 8
NUMBER OF LINES: 236
CONFIGURATION: 0

STEP	FSC	RANGE	NOMINAL	TOLERANCE	MOD1	MOD2	3	4	CON
1.001	ASK-		N						W
1.002	HEAD		TIP Readiness						
1.003	DISP		Verify/Install 'LO/GUARD' shorting links @ TIP for:						
1.003	DISP		5440x 5450A 5500A 850xA						
1.004	HEAD		Skill Requirements						
1.005	DISP		Manual operation of 845 null detector						
1.005	DISP		Manual operation and self-cal of 752A and 720A						
1.006	HEAD		Equipment Used						
1.007	DISP		Fluke Models 845x, 732A, 752A and 720A						
1.008	HEAD		Performance Verification Cables (PVC's) Used						
1.009	DISP		PVC's #1, 2, 3 and 4						
1.010	HEAD		Adaptors Used						
1.011	DISP		Lo Thermal EMF Dual Banana Socket to Dual Spade Lug						
1.012	HEAD		Jumpers Used						
1.013	DISP		Banana plug/banana plug jumpers used for 'Grounds'						
1.013	DISP		1ea. 12 inches long						
1.013	DISP		3ea. 24 inches long						
1.014	HEAD		Loads Used						
1.015	DISP		500 Ohm +/- 5%, 1/2W resistor						
1.016	HEAD		Preliminary Connections						
1.017	DISP		Figure 544xx-PV-1 provides connection information						
1.018	DISP		Install shorting links between:						
1.018	DISP		752A 'GUARD' & 'GROUND'						
1.018	DISP		732A 'GUARD' & 'GROUND'						
1.018	DISP								
1.018	DISP		Remove shorting links between:						
1.018	DISP		845 'INPUT LO' & 'GUARD'						
1.019	DISP		Connect 'Ground' Jumpers as follows:						
1.019	DISP		From 544xx 'GUARD' to TIP 'GROUND'		(12 inch)				
1.019	DISP		From TIP 'GROUND' to 752A 'GUARD'		(24 inch)				
1.019	DISP		From TIP 'GROUND' to 732A 'GUARD'		(24 inch)				
1.019	DISP		From TIP 'GROUND' to 845x 'GUARD'		(24 inch)				
1.020	DISP		Connect PVC's as follows:						
1.020	DISP								
1.020	DISP		# 1 Joined end to 845 'INPUT HI, LO' & 'GUARD'						
1.020	DISP		Free 'Hi/Lo' to 752A 'NULL DETECTOR HI/LO'						
1.020	DISP		# 3 Joined end left unconnected at this time						
1.020	DISP		Free 'Hi/Lo' to 752A 'INPUT HI/LO'						
1.020	DISP		# 4 Joined end to 752A 'REFERENCE SID. HI/LO/GUARD'						

```
1.020  DISP          Free 'Hi/Lo' to 732A '10V HI/LO'
1.021  HEAD        Preparation of 752A
1.022  OPBR        Does the 752A need to be self-cal'd
1.023  JMPF        1.027
1.024  DISP        Connect PVC's as follows:
1.024  DISP
1.024  DISP        # 3 Joined end to 544xx 'OUTPUT HI/LO/GUARD'
1.025  CALL        752A SELF-CAL
1.026  DISP        Remove PVC's as follows:
1.026  DISP
1.026  DISP        # 3 Joined end from 544xx 'OUTPUT HI/LO/GUARD'
1.026  DISP            (Free 'Hi/Lo' remain connected to 752A)
1.027  HEAD        Entry of Calibration Constants
1.028  MEMI        Enter certified value of 732A '10V OUTPUT' in volts
1.029  MEME                                                    >3
1.030  MEM/        100
1.031  MEME                                                    >1
1.032  MEM-        10
1.033  MEME                                                    >2
1.034  MEM+        20
1.035  MEME                                                    >4
1.036  MEM*        5
1.037  MEME                                                    >5
1.038  MEM-        10
1.039  MEME                                                    >6
1.040  HEAD        Internal Calibration of 544xx
1.041  DISP        Ensure no PVC's attached to 544xx 'OUTPUT' or 'DIVIDER'
1.041  DISP
1.041  DISP        OK for 544xx 'Guard' to 'Ground' jumper to be attached
1.042  5440        CAL                                          S
1.043  MESS        Prepare to measure a null with the 845
1.043  MESS        Adjust 5440B output for a null, +/- 0.5 uV
1.043  MESS
1.043  MESS        Set the 845 to the 100V range, then press 'ADV'
1.044  HEAD        Test Connection for 'Divided Output' Verification
1.045  DISP        Set 845 to '100V RANGE'
1.045  DISP
1.045  DISP        Connect PVC's as follows:
1.045  DISP
1.045  DISP        # 3 Joined end to 544xx 'DIVIDER HI/LO/GUARD'
1.046  HEAD        (0.22V Divided Output Range Verification)
1.047  MEME                                                    <1
1.048  DISP        Set the 752A to 'OPERATE', '0.1V MODE'
1.049  5440        V               .0001%                  N  2W
1.050  MEME
1.051  MEME                                                    <1
1.052  MEME
1.053  MEMC        V               .000001050
2.001  RSLT
2.002  HEAD        (2.2V Divided Output Range Verification)
2.003  MEME                                                    <2
2.004  DISP        Set the 752A to '1.0V MODE'
2.005  5440        V               .0001%                  N  2W
2.006  MEME
2.007  MEME                                                    <2
2.008  MEME
2.009  MEMC        V               .000006U
3.001  RSLT        -
3.002  HEAD        Test Connection for 11V Direct Output Verification
3.003  DISP        Relocate PVC's as follows:
```

```
3.003  DISP
3.003  DISP        # 3 Joined end to 544xx 'OUTPUT HI/LO/GUARD'
3.004  HEAD        (11V Range Verification)
3.005  MEME                                                <3
3.006  DISP        Set the 752A to '10V MODE'
3.007  5440        V              .0001%                        N  2W
3.008  MEME
3.009  MEME                                                <3
3.010  MEME
3.011  MEMO        V              .000045U
4.001  RSLT        =
4.002  HEAD        (275V Range Verification)
4.003  MEME                                                <5
4.004  DISP        Set the 752A to '100V MODE'
4.005  5440        V              .0001%                        N  2W
4.006  MEME
4.007  MEME                                                <5
4.008  MEME
4.009  MEMO        V              .000520U
5.001  RSLT        =
5.002  HEAD        (1100V Range Verification)
5.003  MEME                                                <6
5.004  DISP        Set the 752A to '1000V MODE'
5.005  5440        V              .0001%                        N  2W
5.006  MEME
5.007  MEME                                                <6
5.008  MEME
5.009  MEMO        V              .0049U
6.001  RSLT        =
6.002  HEAD        Prepare for 22V Range Verification
6.003  DISP        Remove PVC's as follows:
6.003  DISP        # 3 Free 'Hi/Lo' from 752A 'INPUT HI/LO'
6.003  DISP        # 1 Free 'Hi/Lo' from 752A 'NULL DETECTOR HI/LO'
6.003  DISP        # 4 Joined end free ends from 720A and 752A
6.004  DISP        Remove 'Ground' jumper as follows:
6.004  DISP         from 752A 'GUARD' terminal only
6.004  DISP         (leave connected to TIP 'GROUND')
6.004  DISP
6.004  DISP        NOTE: The 752A is not used in remaining 544xx tests
6.005  DISP        Connect 'Ground' jumper removed from 752A 'GUARD' to:
6.005  DISP         720A '1.0 INPUT GROUND'
6.005  DISP         (Other end remains connected to TIP 'GROUND')
6.006  OPER        Does the 720A need to be self-cal'd
6.007  JMPF        6.014
6.008  HEAD        720A Self-Cal
6.009  DISP        Figure 720A-SC-1 provides connection information
6.010  DISP        Connect PVC's as follows:
6.010  DISP
6.010  DISP        # 3 Free 'Hi/Lo' to 720A 'BRIDGE POWER HI/LO'
6.010  DISP        # 1 Free 'Hi/Lo' to 720A 'BRIDGE DETECTOR HI/LO'
6.011  CALL        720A SELF-CAL
6.012  DISP        Remove PVC's as follows:
6.012  DISP
6.012  DISP        # 3 Free 'Hi/Lo' from 720A 'BRIDGE POWER HI/LO'
6.012  DISP        # 1 Free 'Hi/Lo' from 720A 'BRIDGE DETECTOR HI/LO'
6.013  HEAD
6.014  HEAD        (22V Range Verification)
6.015  DISP        Figure 544xx-PV-2 provides connection information
6.016  HEAD        Adapter Connection
6.017  DISP        Connect Lo Thermal EMF Dual Banana Socket/Spade Lug
```

```
  6.017  DISP          Adaptor to 720A '1.0 INPUT HI/LO' via Spade Lugs
  6.018  DISP          Connect PVC #4 as follows:
  6.018  DISP           Joined end to 544xx 'SENSE HI/LO' & 'OUTPUT GUARD'
  6.018  DISP           Free 'Hi/Lo' to 720A '1.0 INPUT' Adaptor Sockets
  6.019  DISP          Connect remaining PVC's as follows:
  6.019  DISP
  6.019  DISP          # 3 Free 'Hi/Lo' to 720A '1.0 INPUT HI/LO'
  6.019  DISP          # 1 Free 'Hi' to 720A 'OUTPUT HI'
  6.019  DISP              Free 'Lo' to 732A '10V OUTPUT HI'
  6.019  DISP          # 2 'Guard' end to 720A 'OUTPUT LO/GUARD'
  6.019  DISP              Free end to 732A '10V OUTPUT LO'
  6.020  DISP          Set the 720A to 0.5000000
  6.021  MEME                                                    <4
  6.022  DISP          Prepare to measure CMEMJV with 720A. 732A & 845
  6.023  5440          V               .0001%                          N  4W
  6.024  MEME
  6.025  MEME                                                    <4
  6.026  MEME
  6.027  MEM           V               .00004130
  7.001  RSLT
  7.002  HEAD          (Load Regulation)
  7.003  DISP          Set the 720A to 0.999999X
  7.004  MESS          Adjust 544xx output for null, +/- 0.5uV on 3uV range
  7.004  MESS          Connect 500 Ohm load across 720A '1.0 INPUT HI' & 'LO'
  7.004  MESS          Note that the change in 845 indication is less than 1uV
  7.004  MESS
  7.004  MESS          Set the 845 to the 100V range, then press 'ADV'
  7.005  5440          10V             .0001%                          N  4W
  7.006  MESS
  7.007  EVAL    Was (Change in 544xx output less than 1 uV)?
  8.001  HEAD          Conclude Testing or Procede to 5450A Verification
  8.002  OPBR          Will the 5450A be verified next ?
  8.003  JMP           8.010
  8.004  HEAD          Procede to 5450A Verification
  8.005  DISP          Leave PVC's connected as follows:
  8.005  DISP
  8.005  DISP          # 1 Joined end at 845 'INPUT HI/LO/GUARD'
  8.005  DISP          # 2 'Guard' end at 720A 'OUTPUT LO'
  8.005  DISP          # 3 Free 'Hi/Lo' at 720A '1.0 INPUT HI/LO'
  8.006  DISP          Remove PVC connections as follows:
  8.006  DISP          # 1 Free 'Hi' from 720 'OUTPUT HI'
  8.006  DISP              Free 'Lo' from 732A '10V HI'
  8.006  DISP          " 2 Free end from 732A '10V LO'
  8.006  DISP          # 3 Joined end from 544xx 'OUTPUT HI/LO/GUARD'
  8.006  DISP          # 4 Entirely
  8.007  DISP          Remove 'Ground' jumpers as follows:
  8.007  DISP           From '544xx OUTPUT GUARD' to TIP 'GROUND'
  8.007  DISP           From 732A 'GUARD' end only
  8.007  DISP             (Other end remains at TIP 'GROUND')
  8.008  DISP          The remaining connections will be used at the beginning
  8.008  DISP          of the 5450A PV,  The loose ends of PVC's #1 & 2 and the
  8.008  DISP          'Ground' jumper will be connected them.
  8.009  JMP           8.012
  8.010  HEAD          End of Verification
  8.011  DISP          Remove all Jumrers, Adartors and PVC's
  8.012  HEAD
END
```

JOHN FLUKE MFG. CO., INC. A123 PROCEDURE

INSTRUMENT: 752A SELF-CAL

DATE: 12-Apr-86
AUTHOR: F. CAPELLI
REVISION: 0

ADJUSTMENT THRESHOLD: 70%

NUMBER OF TESTS: 1
NUMBER OF LINES: 7
CONFIGURATION: 0

STEP	FSC	RANGE	NOMINAL	TOLERANCE	MOD1	MOD2	3	4	CON
1.001	5440		20V				S		2W
1.002	DISP		544x is supplying 20V						
1.002	DISP								
1.002	DISP		Self-cal 752A then press 'ADV'						
1.003	5440		*				S		
1.004	HEAD								

END

JOHN FLUKE MFG. CO., INC. A123 PROCEDURE

INSTRUMENT: 720A SELF-CAL

DATE: 12-Apr-86
AUTHOR: F. CAPELLI
REVISION: 0

ADJUSTMENT THRESHOLD: 70%

NUMBER OF TESTS: 1
NUMBER OF LINES: 31
CONFIGURATION: 0

STEP	FSC	RANGE	NOMINAL	TOLERANCE	MOD1	MOD2	3	4	CON
1.001	5440		20V				S		2W
1.002	DISP		544xx is supplying 20V						
1.002	DISP								
1.002	DISP		Self-cal 'A' decade, then press 'ADV'						
1.003	5440		10V				S		2W
1.004	DISP		544xx is supplying 10V						
1.004	DISP								
1.004	DISP		Self-cal remainder of 720A, then press 'ADV'						
1.005	5440		*				S		
1.006	HEAD								

END